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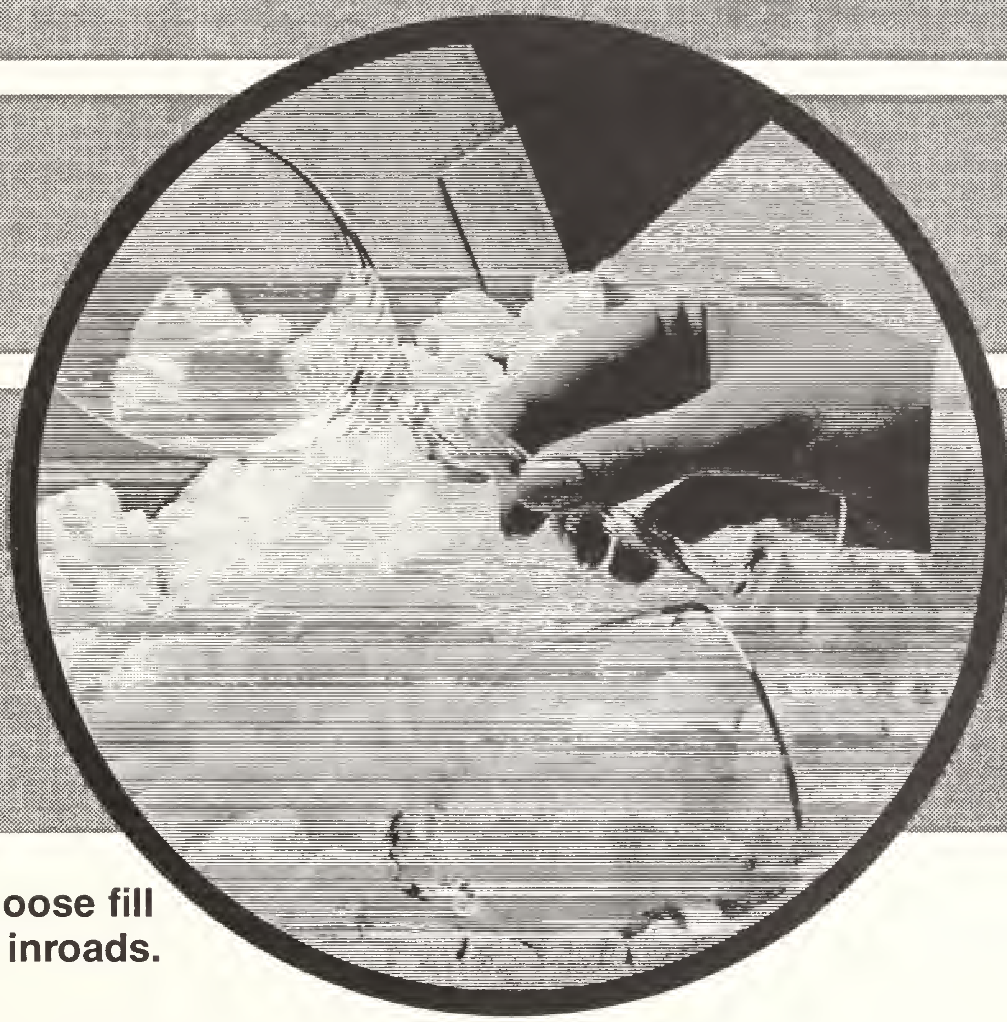
Industrial Uses Of Agricultural Materials

Situation and Outlook Report



Starch-based loose fill makes market inroads.

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Summaries and text may be accessed electronically. Call ERS Customer Service, (202) 219-0515 for details.

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Summary

Greater Planting Flexibility and Industrial Uses Provide More Market Opportunities for Agriculture

With U.S. farmers now facing few restrictions on what they can plant, industrial crops will need to stay competitive—economically and agronomically—with other crops to ensure their continued viability. Expanded planting flexibility is a hallmark of the recently passed Federal Agriculture Improvement and Reform Act of 1996 (1996 Act). The 1996 Act takes the United States to an almost fully market-oriented farm policy by eliminating annual supply control programs, instituting near full planting flexibility, and decoupling income support from production and market prices. The 1996 Act allows farmers greater freedom to respond to market incentives. Therefore, expected market returns and crop rotation needs or desires will become important factors as farmers evaluate commodities to produce in the future.

The 1996 Act also made USDA's Alternative Agricultural Research and Commercialization (AARC) Center a wholly owned government corporation. In addition, the Act amends Federal procurement policy to encourage Federal agencies to give procurement preference to environmentally friendly products produced by companies supported by the AARC Corporation.

Scientific developments from USDA's Agricultural Research Service are now posted on the Internet. Industry, the scientific community, and consumers can use this Internet service to target specific interests. More than 13,000 research project reports are available on the agency's Technology Transfer Automated Retrieval System.

The strong growth in U.S. gross domestic product in the second quarter of 1996 is expected to give way to more moderate growth for the rest of 1996 and 1997. Reflecting moderating growth, manufacturing output is expected to rise at an average annual rate of 3.5 to 4.5 percent through the end of 1997. As mature industries in a mature economic recovery, most of the industrial sectors using agricultural inputs will grow more slowly than manufacturing overall.

Industrial uses of corn are expected to total 622 million bushels in 1995/96 (September/August), down 18 percent from the previous year, mainly due to lower use for ethanol. Ethanol producers are in the midst of a financial squeeze, resulting from rapidly rising corn prices, only moderate gains in coproduct prices, and relatively stable ethanol prices. Several companies are manufacturing biodegradable loose-fill packaging materials from corn and wheat starch.

Industrial vegetable oil markets reflect a varied picture of production and use. Tung oil is being produced in the United States for the first time since 1973. Crambe is again being grown in North Dakota after a year of no commercial production. Industrial rapeseed acreage in the Pacific Northwest is down from previous years. Glycerine markets remain tight, as demand continues to outpace supply. Biodiesel commercialization faces a number of regulatory and market challenges in the United States.

Approximately 37 million metric tons of paper and wood materials were recovered for recycling in 1994, providing a renewable source of inputs to manufacturers. Beside paper and paperboard products, other items made from recycled paper and wood include cellulose insulation, molded-pulp products, animal bedding, paper mulch, packaging cushioning material, and wallboard panels. Finding new markets for wastepaper and waste wood is essential to the growth of the recycling industry.

To meet environmental regulations of the last three decades, environmental remediation has developed into a multibillion dollar industry. The high cost of many traditional methods is causing many organizations to look to lower cost alternatives. Phytoremediation, the systematic use of plants to treat environmental contamination, is a potential low-cost technology that is being investigated for many remediation applications.

A special article examines possible biodiesel demand in three niche fuel markets the biodiesel industry has identified as likely candidates for commercialization—Federal fleets, mining, and marine/estuary areas. If a 20-percent biodiesel blend becomes a competitive alternative fuel in the coming years, these markets could demand as much as 100 million gallons of biodiesel. If soybean oil was the sole feedstock used to produce the biodiesel, these markets could account for an additional 770 million pounds of soybean oil. Results of an econometric-based simulation indicate the effect of this increase in demand on the U.S. soybean complex and net farm income would be small. Moreover, if biodiesel commercialization occurs, cheaper raw materials, such as waste cooking oil, may be the primary feedstocks.

1996 Farm Legislation Affects Industrial Crops And Products

Expanded planting flexibility is one of the hallmarks of the recently passed Federal Agriculture Improvement and Reform Act of 1996 (1996 Act). The 1996 Act also amends Federal procurement policy to give preference to environmentally friendly products produced by companies supported by USDA's Alternative Agricultural Research and Commercialization Corporation. Scientific developments from USDA's Agricultural Research Service are now available on the Internet.

1996 Act Makes Major Changes In Commodity Programs

Since the 1930's, agricultural legislation has been enacted to stabilize and boost farm income. Farm laws originally enacted in 1938 and 1949 are considered permanent legislation, because they do not have a specified termination date. However, since their original passage, these two laws have been amended with new farm legislation about every 4 to 5 years, temporarily setting agricultural policy and guiding farm production. One general result was to link production and marketing controls with price and income support for many important farm commodities, such as wheat, corn, cotton, rice, sugar, tobacco, and peanuts. During fiscal years 1989 through 1995, annual payments to farmers producing wheat, feed grains, cotton, and rice have totaled more than $40 billion, averaging $5.8 billion annually.

In 1995 and 1996, Congress considered farm legislation to replace the expiring Food, Agriculture, Conservation, and Trade Act of 1990 (1990 Act). The result was the Federal Agriculture Improvement and Reform Act of 1996, which was signed into law on April 4, 1996, and covers crop years 1996 through 2002. Title I of the 1996 Act provides set payments and a nonrecourse loan program with marketing loan provisions for wheat, feed grains, cotton, and rice. Soybeans and minor oilseeds (sunflower seed, canola, industrial rapeseed, safflower, flaxseed, and mustard seed) receive only the nonrecourse loan program with marketing loan provisions. One of the stated purposes of the 1996 Act is to improve the operation of the farm programs for milk, peanuts, and sugar.

The 1996 Act will likely become another landmark in U.S. agricultural policy. It takes a major step toward phasing out some aspects of commodity programs that have existed, in some form, since the 1930's. For example, it takes the United States to an almost fully market-oriented farm policy by eliminating annual supply control programs, instituting near full planting flexibility, and decoupling income support from production and market prices.

Dependence on market forces will generate economic efficiency gains and make the U.S. farm sector more competitive in the global marketplace. However, farm income may become more variable and, therefore, producers will have more responsibility for managing income risk, a previous role of the Federal Government that is sharply reduced under the 1996 Act.

One major change that will be of particular interest to individuals and businesses involved in industrial crop production is the planting flexibility provisions. Farmers planting minor oilseeds, alternative crops (such as sesame, plantago ovato, and triticale), and industrial crops (such as crambe, meadowfoam, kenaf, and milkweed) will be able to plant any amount of these crops without program restrictions.

New Production Flexibility Contracts

Production flexibility contracts (PFC) are the new method of providing payments to farms that produce wheat, feed grain, cotton, and rice. Deficiency payments, which fluctuated depending on market prices, are eliminated and replaced with PFC payments. PFC's provide set payments to program participants regardless of production levels or season-average farm prices. The total amount available for PFC payments is fixed in advance and declines gradually over the 7-year life of the 1996 Act. PFC payments are based on contract acreage and the farm-program-payment yield (similar to crop-acreage base and program yield under the 1990 Act and other previous farm bills). Annual acreage reduction programs, 0/85/92 and 50/85/92 programs, and the Farmer-Owned Reserve are not authorized for 1996 through 2002.

Any producer with an established crop-acreage base who had land enrolled in an annual acreage reduction program in at least 1 of the past 5 years, or who had land that was considered planted, was eligible to sign a PFC. Sign-up began May 20, 1996, and extended through August 1, 1996. However, there is an exception to this one-time sign-up. Acreage in Conservation Reserve Program contracts expiring after August 1 will be permitted to enter the program if these acres were part of a farmer's crop acreage base. Producers signing contracts have to comply with conservation, wetland, planting-flexibility, and land-use requirements. All PFC's, unless terminated earlier, will extend through the 2002 crop. As of August 20, 1996, 98.8 percent of estimated eligible acreage had been enroled in PFC's.

For fiscal years 1996 through 2002, the 1996 Act allocates a total of $35.6 billion for contract payments. An individual annual contract payment is calculated as the contract-

payment quantity (in bushels, pounds, or hundredweight) times the annual payment rate (dollars per bushel, pound, or hundredweight). Although the annual payment rates will not be known until after sign-up, they will be affected by total participating base acreage, program yields associated with that base acreage, and any adjustments made to the total payment amount based on deficiency-payment refunds or repayments, or terminated contracts. Annual contract payments will be made by September 30th each year.

Under the 1996 Act, producers may plant any commodity or crop on contract acreage (although there are restrictions on fruit and vegetable production) and still receive an annual payment. In general, fruits and vegetables cannot be produced on contract acreage, but if a history of fruit and vegetable cropping exists on contract acres, production may continue in some cases with a corresponding acre-by-acre drop in payments for that year. Haying or grazing on all contract acreage, including unlimited planting of alfalfa and other foliage, may occur at any time during the year without loss of an annual payment. Planting a crop is not required for payment eligibility. Farmers, however, must use contract acreage for some agricultural or related activity and not for nonagricultural commercial or industrial purposes.

The 1996 Act orients production agriculture to market returns by allowing farmers to respond to market incentives, instead of government programs. Expected market returns and rotational needs or desires will become major determining factors as producers evaluate commodities to produce in the future. Because producers will know what their PFC payments will be until 2002, they will have greater freedom to implement multiyear crop rotations and production plans. Therefore, industrial-crop returns must stay competitive, economically and agronomically, with other crops to provide farmers with production incentives. Marketing and contractual relationships and vertical coordination developed in recent years will be important, as producers secure markets for industrial crops and processors secure quality supplies.

Nonrecourse, marketing-assistance loans are available for each loan commodity (wheat, corn, barley, grain sorghum, oats, extra-long-staple cotton, upland cotton, rice, soybeans, sunflower seed, canola, industrial rapeseed, safflower, mustard seed, and flaxseed) for the 1996 through 2002 crops. The general loan provisions from the 1990 Act are continued under the 1996 Act. Producers can place eligible production under loan in return for receiving the commodity loan rate. Marketing loan provisions are not available for extra-long-staple cotton but are continued for wheat, feed grains, upland cotton, rice, soybeans, and minor oilseeds. Producers may repay nonrecourse, marketing-assistance loans at the lesser of the loan rate plus interest or the repayment rate, which may fall below the loan rate to minimize government stock holding and allow for competitive markets.

Minimum loan rates will be calculated as 85 percent of a moving average of the last 5 years' market prices, excluding years with highest and lowest prices, subject to maximums set equal to the 1995 loan rate. Corn and wheat loan rates may be further reduced based on stocks-to-use ratios. Sorghum, barley, and oats loan rates are set in relation to the rate for corn, taking into account their feed value relative to corn. The rice loan rate is set at $6.50 per hundredweight. Loan rate ranges have been set for several commodities: soybeans will range between $4.92 to $5.26 per bushel; minor oilseeds, between 8.7 and 9.3 cents per pound; and upland cotton, between 50 and 51.92 cents per pound. The loan rate for extra-long-staple cotton is subject to a maximum of 79.65 cents per pound.

The maximum a person can receive in PFC payments is $40,000 per year, down from the previous limit of $50,000. An individual's limit on payments from marketing-loan provisions, marketing-loan gains, or loan-deficiency payments continues at $75,000.

NAP May Also Benefit Industrial Crop Producers

Another change implemented by the 1996 Act is that producers who receive farm program benefits are not required to obtain crop insurance, if the producer waives emergency crop loss assistance. For those crops not currently covered by crop insurance, USDA is instructed to continue to operate a noninsured crop disaster assistance program (NAP). USDA's Office of Risk Management offers crop insurance, including catastrophic coverage, for major field crops and many fruits and vegetables.

NAP will provide producers of noninsured crops with coverage equivalent to the catastrophic risk protection available to producers of major commodities, provided that an area-based yield trigger is first met. Industrial rapeseed (on a pilot basis) and flaxseed are currently the only industrial crops eligible for crop insurance. Research is underway examining the feasibility of insuring crambe, specialty canolas, and other noninsured crops. NAP is administered by USDA's Farm Service Agency (FSA) and funded by the Commodity Credit Corporation. NAP covers various fruits and vegetables, floriculture, ornamental nursery, Christmas tree crops, turfgrass sod, seed crops, aquaculture, and noninsured industrial crops.

NAP requires both an area trigger and an individual trigger for a producer to collect a payment. An area must have a yield loss of 35 percent, and may be defined, at the discretion of the State FSA director, as a county, a geographic area with at least 320,000 acres, or a geographic area with a crop value of at least $80 million. To date, virtually all areas have been defined using the county definition. In addition to the area trigger, an individual producer must have a crop loss of at least 50 percent of the expected yield. NAP payments are based on established yields for the crop and an average market price or comparable coverage determined by the Secretary of Agriculture. For crop years 1996 through 1998, 60 percent of the average market price or comparable coverage is recoverable. For crop years 1999 through 2002, 55 percent of the average market price or comparable coverage is recoverable.

A third part of the 1996 Act that may be of interest to industrial crop producers and processors is the research title (Title VIII), which amends the National Agricultural Research, Extension, and Teaching Policy Act of 1977 (NARETPA). As amended by the 1996 Act, the purposes

of federally supported research, extension, and education are to increase and enhance competitiveness and productivity of U.S. agriculture, develop new uses and new products for agricultural commodities, aid with technology transfer, improve risk management in the U.S. agricultural industry, improve safe production and processing of food while maintaining a balance between yields and environmental soundness, support higher education, and maintain safe food supplies to meet human requirements. For example, Title VIII Section 806 relates to grants for research or the production and marketing of alcohol and industrial hydrocarbons from forest products and agricultural commodities. The 1996 Act extends authority for appropriations on agricultural research, extension, and education activities under NARETPA through fiscal 1997.

Government Encouraged To Buy AARC Products

The 1996 Act also made USDA's Alternative Agricultural Research and Commercialization (AARC) Center a wholly owned government corporation. In addition, there is language in the Act's rural development title amending Federal procurement policy to encourage Federal agencies to give procurement preference to environmentally friendly products produced by companies supported by the AARC Corporation.

The intent of the new procurement language is to give Federal procurement officials the latitude to establish set-asides and preferences for AARC Corporation-supported, environmentally preferable products. Some argue that since the Federal Government has taken an equity position in these companies, the American people are, in essence, stockholders. The quicker these companies can become profitable, the faster they can repay the Federal investment. Their repayments go into the AARC Corporation revolving fund to be reinvested in other companies, thereby continuing the process of creating new economic opportunities in rural communities, while protecting the environment. The procurement preference is not open-ended. The preference eligibility will expire 5 years after companies have repaid their investment to the AARC Corporation, or no longer than 10 years after companies receive support from the Corporation.

The AARC Corporation supports companies that have a variety of products now on the market, including absorbents; biocontrol agents and planting media; construction materials and composites; coatings and films; cosmetics; cleaning agents, solvents, detergents, and surfactants; degradable polymers; filler, yarn, and insulations; fuels; inks; lubricants; pharmaceutical and veterinary products; and paper and packaging. Interested persons should contact the AARC Corporation for a catalog of supported products and more information (phone 202-690-1633, fax 202-690-1655, e-mail rbuckhal@rus.usda.gov). This report is printed on kenaf paper supplied by KP Products, an Albuquerque, New Mexico company, in which the AARC Corporation has invested.

Secretary Glickman Tours Office Built With AARC Products

On April 24, 1996, Secretary of Agriculture Dan Glickman and Deputy Secretary Richard Rominger, along with Federal Environmental Executive Fran McPoland, toured the new Washington, DC, headquarters of the Natural Resource Defense Council (NRDC). NRDC is using many "green" products in its new offices.

Four construction products supported by the AARC Corporation were used at the NRDC headquarters at 1200 New York Avenue, NW:

- Nonload-bearing walls (*EnviroPanels*) and interior doors in the office were made from compressed wheat straw by Stramit U.S.A. in Perryton, Texas.

- Cabinets were fashioned from *PrimeBoard,* fiberboard made from 100-percent wheat straw with no noxious chemical additives, by PrimeBoard, Inc., of Wahpeton, North Dakota.

- The counter tops for computers and work stations were made from *Environ*, a composite material manufactured from soybean meal and waste newspaper. Environ looks like marble but can be handled like wood, and is produced by Phenix BioComposites in St. Peter, Minnesota.

- Strong, lightweight *Gridcore* panels for furniture and office partitions were manufactured using recycled paper or kenaf fibers by Gridcore Systems International of Long Beach, California.

Some 25 percent of the AARC Corporation's partners are involved in construction and the building-products industry. Other construction-related materials in the AARC Corporation portfolio that were not used in the NRDC office include:

- Load-bearing wall panels made from wheat straw by Agri-Board Industries of Fairfield, Iowa, and Coppell, Texas;

- A composite material made from recycled plastic and wheat straw for outdoor use in posts, railroad ties, decks, docks, window and door frames manufactured by XY-MAX, Inc., of Mankato, Kansas;

- Lightweight, extended-life utility poles, constructed by joining tapered wood staves with veneer wraps, made by PoleTech, Inc., of North Branch, Minnesota; and

- An environmentally friendly concrete-form release agent made from crambe and/or industrial rapeseed oil by the Leahy-Wolf Company of Franklin Park, Illinois.

More Repayments Received

Although the AARC Corporation has been making investments for only 4 years, it has already begun to receive paybacks from six companies. The first paybacks came in 1995 from Leahy-Wolf and Natural Fibers of Ogallala, Nebraska, which manufactures pillows and comforters using milkweed floss and markets the products internationally.

Thus far in 1996, the AARC Corporation has received paybacks from:

- BioPlus, Inc., of Ashburn, Georgia, which uses peanut hulls as the carrier base for crop protection materials and as flushable cat litter;
- Aquinas Technologies of St. Louis, Missouri, which produces and markets ethanol-based products made from corn, including a windshield washer fluid, *America's Solution*, that will soon be available nationwide;
- Innovative Biosystems of Moscow, Idaho, which uses crop residues to make potting mix; and
- Midwest Biofuels, a subsidiary of Interchem Environmental, Inc., of Overland Park, Kansas, which uses soybean methyl esters to make a variety of products including biodiesel and cleaning solvents.

In its first 4 years of funding, the AARC Corporation has invested $28 million in projects in 32 States, and has leveraged $112 million in private funds, creating over 5,000 jobs in rural communities.

ARS Technology Transfer Continues

Scientific developments from USDA's Agricultural Research Service (ARS) are now available on the Internet. More than 13,000 research project reports are available on the agency's Technology Transfer Automated Retrieval System (TEKTRAN) at http://www.nal.usda.gov/ttic/tektran/tektran.html. Industry, the scientific community, and consumers can use this Internet service to target specific interests. Projects can be searched by keywords, such as commodity type, potential industrial application, and scientific discipline. Entries of newly completed research projects submitted for publication are added to TEKTRAN on a biweekly basis.

In addition, information on licensable patents and patent applications can be accessed through TEKTRAN's link to the National Agricultural Library. Licensable patent information is updated each month and kept current by ARS' Office of Technology Transfer (OTT). Inventor addresses, and phone and fax numbers accompany each entry to expedite commercialization efforts of ARS-developed technology. A planned OTT home page is expected to offer a full range of technology transfer opportunities and services.

The agency's longstanding commitment to improving the commercial viability of biofuels continues. For example, two patent applications on technology developed by ARS scientists in Philadelphia, Pennsylvania, were filed recently that specifically address this issue. One invention involves enzymatic production of a fuel additive, using oilseed byproducts, that can be added directly to automotive fuels. A second invention uses inexpensive feedstocks, such as rendered fats and restaurant grease, to make biodiesel, as well as to produce fuel additives and lubricants.

ARS's technology transfer efforts continued in fiscal 1996, with the agency signing a number of Cooperative Research and Development Agreements (CRADA's) and licensing agreements with U.S. firms. (CRADA's allow joint collaboration between government scientists and industry to develop particular discoveries.) For example, ARS scientists in Albany, California, have entered a CRADA with Tenneco Packaging Company, Inc., of Canandaigua, New York, on the development of biodegradable containers made from wheat starch. The technology also can be used to make a lightweight concrete-like product, which is of particular interest to the high-value ornamental brick and stone market.

Two other CRADA's signed in fiscal 1996 involve the development of composite materials from starch to make products such as fast-food packaging, cutlery, films, and plates. Scientists in Peoria, Illinois, are working with the Biotechnology Research and Development Corporation of Peoria and Tenneco Packaging, Inc., on an extruded starch-based sheeting technology to develop biodegradable alternatives to petroleum-derived plastics.

A variety of food and nonfood applications is being commercialized using a stable, nonseparable composition made from starch and oil. Known as Fantesk, it was developed and patented by ARS scientists in Peoria, Illinois. The Union Camp Corporation of Wayne, New Jersey, was granted an exclusive license to the technology to make environmentally friendly adhesives, glues, and coatings. Opta Food Ingredients of Bedford, Massachusetts, licensed the technology for a variety of food applications, such as fat replacements. Additional companies are working with Opta on sublicensing the technology to develop commercial products. The starch-oil combination also attracted the attention of Seedbiotics, Inc., of Caldwell, Idaho, which will use the technology to encapsulate fertilizers and biological pesticides and hervicides in compositions that can be used to coat seeds to reduce surface-level applicatiom of these compounds. Additional applications of the technology include pharmaceuticals, lubricants, and personal-care products.

In addition, Quincy Soybean Company of Quincy, Illinois, has applied for an exclusive license for an ARS-patented method for manufacturing 100-percent soy inks. Developed by ARS scientists in Peoria, Illinois, the 100-percent soy inks have characteristics that meet or exceed industry standards for product functionality and quality.

The textile industry is showing interest in an improved enzymatic retting process being developed by ARS scientists in Athens, Georgia, to make products from fiber flax. The technology would replace existing enzymatic treatments and dew-retting, which depends on microorganisms and weather conditions to separate flax's long bast fibers from the rest of the stem. The technology should allow textile companies to develop a more consistent product, with high strength and moisture-absorbance characteristics.

A Memorandum of Understanding for Technology Transfer between ARS and the State of Florida, which was signed in November 1995, began to bear fruit in fiscal 1996 with several activities benefiting both organizations. To assist Florida's new port inspection program, ARS notified Florida officials about a patented method developed in Albany, California, that uses imaging technology to inspect plant

materials. Florida officials are working with a business partner to develop a CRADA.

Likewise, Florida officials have assisted in efforts to commercialize a USDA pest-control technology, which uses global positioning systems to target pests, by locating businesses associated with the Kennedy Space Center. Four companies are currently evaluating the commercial potential of this new technology. Florida also forwarded an inquiry from a Fort Lauderdale company concerning the development of a precision fertilizer-injection system. After further investigation, it was determined that this system could also be used to deliver biological pest control materials developed by ARS scientists in Mississippi and Texas. [*1996 Act*: William Bryan Just, ERS, and Linwood Hoffman, ERS, (202) 501-7103, lhoffman@econ.ag.gov. *AARC Corporation*: Ron Buckhalt, AARC Corporation, (202) 690-1633, rbuckhal@rus.usda.gov. *ARS*: Bruce Kinzel, ARS, (301) 504-6965, bmk@ars.usda.gov.]

More Moderate Economic Growth Expected In the Rest of 1996 and 1997

The strong growth in U.S. gross domestic product in the second quarter of 1996 is expected to give way to more moderate growth for the rest of 1996 and 1997. Reflecting moderating growth, manufacturing output is expected to rise at an average annual rate of 3.5 to 4.5 percent through the end of 1997. As mature industries in a mature economic recovery, most of the industrial sectors using agricultural inputs will grow more slowly than manufacturing overall.

U.S. industries that use agricultural inputs tend to be mature industries and, as such, find their economic prospects closely tied to changes in the general U.S. economy. This section provides an overview of the U.S. economy and manufacturing sector, focusing on nine major industries that use agricultural materials.

The U.S. gross domestic product (GDP) grew a robust 4.2 percent in the second quarter of 1996, reflecting strong manufacturing growth. Lumber-and-products output rose as new housing and home improvement projects, delayed by bad weather in the first quarter, began in the second. Also, housing demand was up because strong disposable-income growth from a real increase in total wages paid (employment increased sharply during the quarter) and the use of variable rate mortgages overcame the impact of long-term mortgage rates that were 1 percent higher than at the end of 1995. Transportation-equipment output increased because of car and van rebates, good personal-income growth, rising business spending on vehicles, and dealers rebuilding inventories depleted by the strike at General Motors (GM). Textile-mill production rose because of increased spending on furniture. Chemicals and products and rubber and plastics were hurt by higher energy prices and a strengthening of the dollar that slowed exports and increased imports.

Manufacturing output increased 2.4 percent in the first quarter of 1996, while GDP grew a moderate 2.0 percent (table 1). Of nine major industries using agricultural materials (lumber and products, furniture and fixtures, industrial machinery and equipment, transportation equipment, textile-mill products, paper and products, chemicals and products, rubber and plastic products, and leather and products), only two experienced gains in the first quarter. Industrial machinery and equipment grew at an annualized rate of 19.5 percent and chemicals and products increased 1.7 percent. Production dropped in the other seven industries. Lumber-and-products output declined because of unusually bad weather that inhibited construction. The GM strike was responsible for a quarterly decline in transportation-equipment output. Rubber output was stagnant as export sales could not make up for a drop in domestic demand for tires and material on GM cars.

Table 1—Growth rates for GDP, industrial production, and selected industries using agricultural materials

Item	3rd qtr 1995	4th qtr 1995	1st qtr 1996	2nd qtr 1996
	Percent change 1/			
Gross domestic product	3.6	0.3	2.0	4.2
Industrial production	3.2	0.6	3.0	6.0
Manufacturing	2.6	1.4	2.4	6.5
Lumber and products	6.7	4.7	-4.3	14.6
Furniture and fixtures	0.6	-4.8	-2.9	7.9
Industrial machinery and equipment 2/	10.7	18.8	19.5	13.1
Transportation equipment	-2.8	-13.7	-4.8	31.7
Textile-mill products	-9.6	-5.3	-10.4	11.4
Paper and products	-5.5	-4.7	-11.1	17.1
Chemicals and products	2.0	5.9	1.7	-1.9
Rubber and plastic products	-0.6	3.0	-0.1	-0.3
Leather and products	-10.6	-8.5	-8.8	-2.9

1/ Annualized on a quarterly basis. 2/ Overall sector growth. Computers and office equipment grew 23.9, 45.0, 48.4, and 41.4 percent, respectively, during the four quarters. Growth in other industrial-machinery-and-equipment categories was much lower.

Sources: Gross Domestic Product Release, Department of Commerce, Bureau of Economic Analysis, August 1, 1996; and Industrial Production and Capacity Utilization Report, Federal Reserve Bank, Washington, DC, August 15, 1996.

Mature Industries in a Mature Recovery

The current recovery is at a mature stage, which means the robust growth seen in the second quarter will not be reflected in the nine industries. Only the industrial-machinery-and-equipment industry, because of computers and business equipment, and the rubber-and-plastic-products industry are running at capacity utilization rates similar to those of the 1988-89 peak of the last business cycle (table 2). These two industries have also averaged output growth comparable to that of the last two business recoveries that lasted more than 5 years (1961-69 and 1981-89).

Based on capacity utilization behavior and other characteristics, the nine industries generally could be described as mature industries. The chemicals-and-products and non-computer-based-machinery industries are cases in point. Employment growth in these industries is below average for the economy as a whole, and output has not generally

Table 2--Capacity utilization for selected industries using agricultural materials

Item	Peak 1988-89	April 1996	May 1996	June 1996
	Percent			
Total industry	84.9	82.9	83.1	83.2
Manufacturing	85.2	81.8	81.8	82.0
Lumber and products	93.3	89.2	88.3	88.8
Furniture and fixtures	86.8	79.9	81.5	80.8
Industrial machinery and equipment	84.0	89.6	89.6	89.9
Transportation equipment	84.4	74.0	73.9	74.4
Textile-mill products	83.3	81.6	81.2	80.8
Paper and products	94.8	87.7	87.6	86.7
Chemicals and products	85.9	79.5	79.4	79.6
Rubber and plastic products	90.5	87.7	89.6	89.5
Leather and products	83.8	78.0	77.7	78.6

Source: Industrial Production and Capacity Utilization Report, Federal Reserve Bank, Washington, DC, July 1996.

expanded as fast as overall manufacturing. Double-digit output-growth rates, such as those of the technology-driven computer industry, are very unlikely. Finally, the industries they provide with inputs, such as other manufacturers, are also mature, providing only modest growth in derived demand.

Prospects for the Rest of 1996 and 1997

In the second quarter of 1996, the nine major industries using agricultural materials enjoyed a good economic environment. The next year and a half probably will be less favorable as economic conditions will be more like an average of the previous four quarters. While growth in the third quarter of 1996 may be above trend because of the positive impact of the previous two quarters' gains, the fundamentals point to moderate growth for the rest of 1996 and 1997. GDP growth is expected to average 2 to 2.6 percent during the period, with manufacturing output expected to rise 3.5 to 4.5 percent.

Consumers, while stimulated by higher incomes, are not likely to continue accumulating debt as they have for the last year and a half. Credit card and other loan delinquencies are up, so lenders are likely to increase their scrutiny of potential borrowers. Cash-strapped State and local governments, faced with increasing school enrollments and declining Federal assistance, will raise fees and property, income, and sales taxes, further cutting into consumers' spendable income. The 100-basis-point rise in long-term interest rates since late 1995 will further slow consumer durable spending and contribute to lower investment growth.

Investment spending is apparently slowing as manufacturers and resellers of computers, which have led the investment boom of the last 3 years, have recently reported sluggish sales growth. The record increases in profits are moderating, making some slowdown in equipment spending inevitable. The recent strengthening of the dollar versus the German mark and the Japanese yen makes it unlikely that a declining real trade deficit will provide an impetus for growth. Lower Federal spending, only partially offset by higher local spending, will be an additional drag on GDP growth.

Crude oil prices are likely to fall as North Sea and Iranian production expand. Prices are expected to average $18 to $19 per barrel during the next six quarters. If prices do rise, because of unexpected supply disruptions or pressure from higher than expected U.S. and world growth, they are not likely to increase above $25 per barrel due to the large excess capacity held by increasingly independent oil producers.

If the strong growth of the second quarter continues into the summer, the Federal Reserve (Fed) may raise short-term interest rates. Although housing and consumer durable growth will decline soon after any rate hike, a significant slowing of the economy would not be seen for four to six quarters. The banking-credit system, however, is in good shape and, with available funds, lending should not be severely restrained.

Although the economy has been quite strong, capacity utilization is not close to a level presaging inflationary bottlenecks. Productivity has grown faster than wages so far in this expansion, also insulating the economy from a runup in inflation. Greater industrial competitiveness, which makes it hard to pass on wage increases, is another impediment to sharply higher inflation. Thus, there is little chance of higher wages or production bottlenecks starting an inflationary spiral that the Fed will have to choke off with large hikes in short-term interest rates.

Prospects for the Nine Industries Mixed But Modestly Good

None of the nine major industries using agricultural materials should be in recession in 1996 or 1997 due to general economic conditions, but growth will be below that of the first two quarters of 1996. Lumber and products and furniture and fixtures, due to less expected construction activity and slow growth in durable spending by consumers, will likely grow modestly at best, compared with the second quarter. Higher short-term interest rates, if they occur, would further slow construction and durable spending growth.

The prospects for transportation-equipment growth are modest at best, because the domestic light-vehicle market is saturated and local governments are likely too strapped for cash to buy vehicles. However, the U.S. competitive position for airplane exports is good, possibly bringing growth in transportation equipment in one or two of the next six quarters, despite weak fundamentals for the rest of the industry. Production of paper and products and rubber and plastic products is close to full capacity, making growth prospects limited. Rubber is also constrained by the meager prospects for transportation-equipment-output growth.

The major risk to the industries' moderate prospects is stronger GDP growth than the 2- to 2.6-percent average expected for the rest of 1996 and 1997. If growth stays strong, the Fed will raise short-term rates more than currently anticipated. This would likely boost long-term rates as well. Lumber and products and furniture and fixtures

would do well for a quarter or two, then likely be faced with several quarters of declining output. Industrial machinery and equipment and transportation equipment would likely face sharp declines in late 1996 and 1997 with higher interest rates. Chemicals and products and rubber and plastic products would likely do somewhat better in 1996 at the cost of a much weaker 1997. Slow auto industry growth and the likely rise in the dollar from higher U.S. interest rates, which would lower exports, would reduce output and prices in 1997 for most companies in these two industries. [David Torgerson, ERS, (202) 501-8447, dtorg@econ.ag.gov]

Ethanol Production Down, But Packaging And Adhesive Uses Are Up

Industrial uses of corn are expected to total 622 million bushels in 1995/96, down 18 percent from the previous year, mainly due to lower use for ethanol. Ethanol producers are in the midst of a financial squeeze, resulting from a combination of rapidly rising corn prices, only moderate gains in coproduct prices, and relatively stable ethanol prices. Biodegradable loose-fill packaging materials are being manufactured from corn and wheat starch. Almost one-third of all adhesives produced and used in the United States are of natural or renewable origin.

Industrial uses of corn are expected to total 622 million bushels in 1995/96 (September/August), down 18 percent from the previous year (table 3). Corn use for the production of industrial starch, fuel, and manufacturing alcohol will all be lower than in 1994/95, primarily due to this year's high corn prices. In 1996/97, with a larger corn crop, industrial uses of corn are forecast to rise 6 percent from this year's depressed levels to 661 million bushels.

Corn used for ethanol production in 1995/96 is estimated at 395 million bushels, down 26 percent from last year. Higher corn prices have affected fuel ethanol producers, especially dry-mill operations. With corn prices expected to stay strong and ethanol prices held down because of competitive pressures, as of August 1996, producers are expected to keep production low until new-crop corn is available. In 1996/97, ethanol production is likely to partially rebound and use 425 million bushels of corn, which is still below the 1994/95 peak of 533 million bushels.

Corn used to make starch in the first three quarters of 1995/96 declined 4 percent from a year earlier. Starch prices have been strong and may have encouraged some switching to other feedstocks to reduce use. High reported prices suggest producers have passed along the higher costs of corn. Based on elevator bid prices and values of wet-mill byproducts, the net cost of corn for starch has increased sharply during 1996. In May 1996, net corn costs were 9.64 cents per pound, up from 1995's average of 4.34 cents. Use of corn for starch may be up in June to August from a year ago, leaving use for all of 1995/96 down 3 percent from the 226 million bushels used in 1994/95.

In 1995/96, corn used for denatured manufacturing and industrial alcohol is expected to total 40 million bushels, nearly the same as the 36 million used in 1994/95. Current data are only available from the Bureau of Alcohol, Tobacco, and Firearms (ATF) through December 1995 and showed a doubling in corn use for the September through November period. With high corn prices, use will likely slow, as has occurred in prior high-cost periods. In the last half of the marketing year, use is expected to drop significantly below a year earlier. If corn prices decline as expected in 1996/97, corn use in manufacturing alcohol will likely hold its own against other feedstocks and chemical processes for making ethyl alcohol (ethanol).

Revisions Made in the Data on Food And Industrial Uses

Data on food and industrial uses of corn were revised this month following a review of various use categories. These estimates were changed to reflect the numbers reported in the final 1992 Census of Manufacturers. Changes in beverage and manufacturing alcohol also relied heavily on ATF data.

Estimates of corn used to make starch were lowered slightly to reflect Census Bureau numbers. For beverage and manufacturing alcohol, the new series is much more variable and around 20 million bushels larger than previous estimates for recent years. Although licensed by ATF

Table 3--Industrial and food uses of corn, 1990/91-1996/97

Marketing year 1/	HFCS 2/	Glucose and dextrose 2/	Cereals and other products	Starch: Food uses	Starch: Industrial uses	Starch: Total 3/	Alcohol: Beverage	Alcohol: Manufacturing	Alcohol: Fuel	Total industrial use 4/
					Million bushels					
1990/91	379	200	114	33	186	219	54	81	349	616
1991/92	392	210	116	34	191	225	58	103	398	692
1992/93	415	214	117	33	185	218	55	80	426	691
1993/94	444	223	118	33	190	223	51	55	458	703
1994/95	465	231	118	34	192	226	64	36	533	761
1995/96 5/	485	235	118	33	187	220	62	40	395	622
1996/97 6/	505	245	120	35	196	230	70	40	425	661

1/ Marketing year begins September 1. 2/ High fructose corn syrup (HFCS), glucose, and dextrose are primarily used in edible applications, such as food and health care products. 3/ Industry estimates allocate 85 percent of total starch use to industrial applications and 15 percent to food applications. 4/ Industrial uses of starch and manufacturing and fuel alcohol. 5/ Preliminary. 6/ Forecast.

as beverage plants, some ethanol plants also produce fuel or manufacturing alcohol. This necessitated a revision in the data. While the Census of Manufacturers previously published data on beverage industries, the 1992 Census broke out ethyl alcohol production by organic chemical manufactures, including fuel alcohol from wet and dry milling and pure (natural) alcohol. The Census data are within 1 percent of the ATF data, assuming denatured alcohol is 95 percent alcohol and pure alcohol in proof gallons is actually 185 proof. Because alcohol data are reported in proof gallons, tax gallons, and wine gallons, aligning the two sets of data is not always easy. ATF has distinct legal definitions of proof and tax gallons, but in practice a proof gallon and a tax gallon are about the same, both 100 proof, 50 percent ethyl alcohol.

While the ATF and Census data on alcohol production agree, Census numbers on grains used in alcohol production are not available for the organic chemical category to compare with ATF numbers. The ATF data give production of various types of alcohol and total grains used. For alcohol and spirits 190 proof and over, there is a breakout of production by kind of materials used, such as grain, fruit, or ethylene gas. Some simplifying assumptions were used to calculate use. Estimated corn used for beverage and manufacturing alcohol was calculated by taking grain needed and multiplying it by corn's share of total grains as reported by ATF. Grain needed was the sum of estimated grain spirits over 190 proof, less net withdrawals for fuel, grain spirits less than 190 proof, and whiskey production converted to grain at 5.1 proof gallons per 56 pounds of grain. Finally, corn used to produce beer, as reported by ATF, continues to be included in the beverage category.

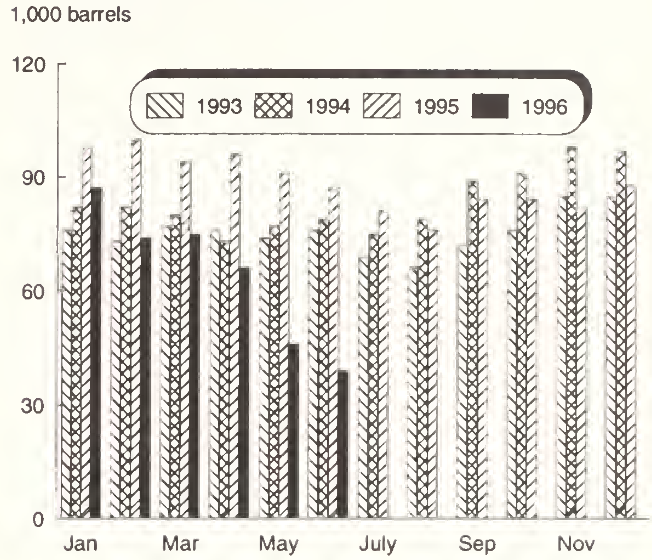
Prices Squeeze Ethanol Producers

Ethanol producers are in the midst of a financial squeeze, resulting from rapidly rising corn prices, only moderate gains in coproduct prices, and relatively stable ethanol prices. The result has been a 30-percent reduction in ethanol production from a year ago, and production is expected to continue falling over the next several months.

Ethanol production is seasonal, picking up in September and October in anticipation of the oxygenated-fuel season that runs from November through February in about 30 cities. Production begins to decline in March and April, as wet millers shift to making sweeteners used in beverages that are in higher demand during the summer (figure 1). Producers also tend to upgrade and perform maintenance on their facilities during the summer, when seasonal demand for ethanol is lower.

Several factors have affected the profitability of ethanol producers in the first 6 months of 1996. First, corn prices have been historically high, exceeding $5 per bushel in Chicago spot markets at one point. Second, while soybean prices have also increased, they have not risen as much as corn prices. Thus, corn prices are higher relative to soybean prices on an historical basis. Prices of coproduct feeds from ethanol production are closely linked to soybean meal prices and, therefore, have not increased as much as corn prices have. Third, until the sharp rise in gasoline prices in February and March, gasoline prices re-

Figure 1
Monthly Ethanol Production



mained steady. Ethanol prices are strongly influenced by gasoline prices, because a large proportion of the ethanol produced in the Corn Belt is blended into regular gasoline as an octane enhancer and fuel extender. Stable gasoline prices have tended to keep ethanol prices from climbing.

The result of these market forces has been an increase in the net cost of corn per gallon of ethanol produced from about 50 cents a year ago to more than $1 now, based on cash prices for corn of $4.80 to $5 per bushel. (Net corn costs include the cost of corn per bushel minus revenue for coproduct feed.) With these costs doubling, producers needed similar increases in ethanol prices to maintain profit margins. Instead, ethanol prices were held in the $1.10 to $1.20 range through April 1996. This combination of rising net corn costs and flat ethanol prices created financial conditions that could not sustain ethanol production in the long run. Not until the effects of the February and March gasoline price spikes had worked their way into the market were ethanol producers able to raise prices and ease tight margins.

Because some ethanol producers engage in hedging and other strategies to limit price risk, they probably have been affected less severely than an analysis using cash prices would indicate. However, some producers found their most profitable course of action was selling their futures positions that had nearly doubled in value and temporarily suspending production, instead of buying corn to produce ethanol. This action on the part of several firms will exacerbate the seasonal reduction in ethanol production and could result in the lowest monthly ethanol production in 10 years.

The outlook for the next 6 months is for lower production and poor margins for producers. As production drops, prices may get a boost because a greater share of ethanol demand will be as an oxygenate in reformulated gasoline markets instead of a fuel extender in conventional gasoline blending. If profit margins for ethanol producers remain

tight, ethanol blending in the conventional gasoline octane/extender market could come to a virtual halt. However, mandated markets for oxygenated fuel and reformulated gasoline will continue to provide a market for ethanol, which remains competitive with other oxygenates in many mandated market areas.

States are continuing their financial support for ethanol producers. While some ethanol plants have been temporarily closed, others in Minnesota have just begun production. These farmer-owned cooperatives are backed by the commitments of their members and a 20-cents-per-gallon State payment.

A good corn crop this year is likely to bring ethanol prices down. August USDA estimates for the 1996/97 marketing year of $3.15 to $3.55 per bushel might be high enough to keep some plants from returning to full production at current gasoline prices. However, the real key to producer profitability is net corn costs per gallon. A more normal alignment between corn and soybean prices should help net corn costs decline after the harvest. If they do, many ethanol producers will begin producing at much higher utilization rates.

Starch-Based Loose Fill Used For Product Packaging

Protective packing materials are used to cushion, protect, and stabilize articles in boxes, cartons, and other containers for shipping and storage. Manufacturers, mail-order firms, and other industries are big users of protective packing materials. The most common materials used to make protective packing are expanded polystyrene (EPS), shredded newsprint, cardboard, excelsior (fine wood shavings), popcorn, and starch. EPS-based, loose-fill foams have enjoyed a steady growth in packaging applications over the last two decades, but are now a target in the solid waste disposal debate because of their nondegradability. Consumers are demanding and legislators are mandating the use of environmentally benign packing materials.

To address the public's concern regarding disposability, biodegradable loose-fill packaging products are being developed and manufactured from corn and wheat starch, and are a growing portion of the loose-fill packaging market. In most cases, starch-based, loose-fill products are 100-percent biodegradable, with the exception of products that contain nondegradable additives. Most starch-based, loose-fill products can be dissolved in water. Smaller quantities could be disposed of in flowerbeds and gardens or simply flushed down the drain to a municipal wastewater treatment facility. Large quantities, which could have detrimental effects on a wastewater treatment facility simply due to the sheer volume of product, would need to be composted; for example, with municipal lawn and garden waste. A 1993 comparative study by the Minnesota Office of Waste Management claims that starch-based loose fill is a reasonable alternative to EPS-based loose fill if composting infrastructures exist and EPS foam recycling is impractical.

Satisfactory performance, good properties, and low cost have enabled EPS-based loose fill to grow over the last 20 years into a successful 90-million-pound-per-year packaging product (*1*). EPS market growth was particularly strong in the 1980's, at more than 20 percent per year. However, many external-market and economic forces, such as the Persian Gulf War, recession, and the switch to alternative packing materials and methods, slowed this growth rate to less than 2 percent during the 1990's. In addition to using alternative loose-fill products, manufacturers have redesigned packages and packing products to use less material. Suppliers conservatively estimate the starch loose-fill market, as of June 1996, at approximately 15 to 20 percent of the EPS loose-fill market. This means that packagers are using 13.5 to 18.0 million pounds of starch loose fill in addition to the 90 million pounds of EPS loose fill.

For starch-based products to have captured some of the loose-fill market means they have had to compete with EPS's performance characteristics. For example, mechanical integrity is important because the function of loose fill is to adequately protect shipped or stored goods. Compression and resiliency tests, conducted by USDA's National Center for Agricultural Utilization Research (NCAUR) in Peoria, Illinois, demonstrated that both starch-based and EPS-based loose fill have similar mechanical integrity. Starch loose fill is more sensitive to changes in relative humidity and temperature than EPS loose fill, but the higher amount of absorbed moisture does not compromise its mechanical properties. A beneficial property that starch loose fill has, which EPS does not, is the ability to resist static cling.

Starch-Based Loose Fill Produced by Several Companies

In general, starch-based packaging products are manufactured using extrusion technology, a process in which the starch is cooked, worked into a plastic-like dough, forced through a die, expanded by loss of moisture and a decrease in pressure, and cooled into a rigid structure with a porous texture. Modified or unmodified starches may be used, depending on the producer and the product. In addition, manufacturers add proprietary additives and other ingredients to develop specific products. Technology typical of the plastics industry molds the starch-based material into final shapes, such as loose fill, sheets, and other forms.

Several companies actively develop, produce, and/or market starch-based loose fill. The products and producing companies are:

- CLEAN GREEN by Clean Green Packing Company of Minneapolis, Minnesota, a wholly owned subsidiary of Environmental Technologies USA, Inc.;
- ENVIROFIL by EnPac, a DuPont/ConAgra Company, of Wilmington, Delaware;
- ECO-FOAM by American Excelsior Company of Arlington, Texas;
- FLO-PAK BIO 8 by Free-Flow Packaging Corporation of Redwood City, California;
- RENATURE by Storopack, Inc., of Cincinnati, Ohio; and

- STAR-KORE by Star-Kore Industries of Memphis, Tennessee, formerly Unistar Industries, Ltd.

Some of these companies produce or distribute other non-starch-based packaging products as well. For example, Free-Flow Packaging manufactures 100-percent, recycled EPS loose fill and American Excelsior manufactures virgin EPS loose fill.

Warner Lambert of Morris Plains, New Jersey, no longer manufactures starch-based resin for loose fill, but licenses the technology to EnPac. National Starch of Bridgewater, New Jersey, licenses its high-amylose starch technology exclusively to American Excelsior Company. Norel Company of Little Ferry, New Jersey, and Storopack, Inc., manufacture and distribute starch loose fill for EnPac under the ENVIROFIL trademark. EnPac sublicenses the Warner-Lambert technology to other companies including Clean Green Packing and Free-Flow Packaging Corporation.

Many companies have recently introduced new-product applications. EnPac has introduced ENVIROMOLD, a wheat-starch, loose-fill material that is dampened with water so the foamed pieces can stick together to form a continuous protective cushion. This product is targeting packagers that use foamed-in polyurethane (liquid chemicals that are combined to form a resilient foam structure) and polyethylene. This market is estimated at about 300 million cubic feet (2). American Excelsior manufactures starch-based extruded shapes and rigid-sheet products for a variety of applications, including end caps, pouches, rolls, and die-cut forms. Other applications recently announced by American Excelsior at the International Agricultural Summit in Kansas City, Missouri, include toys such as foamed logs and blocks, confetti, furniture guards, and potty training aids. Star-Kore Industries has developed flexible- and rigid-sheet products from modified-starch technology.

Starch Loose-Fill Prices Dependent On Corn Prices

Though comparable in function to EPS loose fill, starch-based loose fill is still about 30 percent more expensive. Excluding shipping costs, the average price of commercial starch-based loose fill is 54 cents per cubic foot, while EPS loose-fill prices average about 41 cents per cubic foot from the manufacturer. In addition to being higher priced than EPS loose fill, starch loose fill also has a higher bulk density (weight per cubic foot) than EPS loose fill. This means that an equal volume of starch loose fill in a package will weigh more than an equivalent volume of EPS loose fill. Thus, end users of starch loose fill are hit twice, first by higher purchase prices and then by higher shipping costs due to more weight. However, over the past year, manufacturers of starch-based loose fill have been able to narrow the cost differential between starch and EPS-based foam products due to improvements in manufacturing methods.

Because commercial starch-based loose fill generally contains more than 90 percent starch, the price of a specific loose-fill product is highly dependent on starch prices. (The remaining 10 percent or less consists of additives that facilitate production and improve performance.) Because cornstarch is the cheapest, most widely used industrial starch in the United States, most starch-based loose fill likely is manufactured from cornstarch, although some products may use wheat and/or potato starch.

Good mechanical performance and biodegradability have enabled starch-based loose fill to successfully compete with EPS-based products. Industry sources anticipate continued market growth for starch-based products, as research efforts continue to reduce cost, improve performance, and develop new applications for loose fill and other starch-based foam products. This research is being conducted by starch producers, packaging manufacturers, and USDA laboratories such as NCAUR.

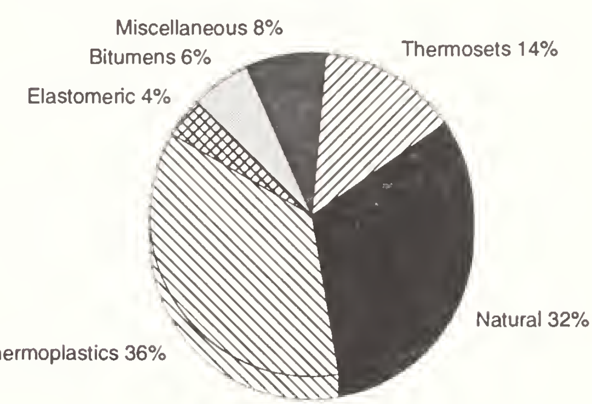
Natural Adhesives Respond to Changing Market Influences

Adhesives are used in a wide variety of applications. Over 1,000 different types of natural and synthetic adhesives are used in the manufacture of textiles, plastics, wood products, ceramics, electronics, glass items, cosmetics, pharmaceuticals, and metals.

Adhesives are one of the leading industrial-product categories that use a large amount of natural raw materials. Almost one-third of all adhesives produced and used in the United States is of natural or renewable origin (figure 2). Natural adhesives are derived from a wide variety of raw materials, including agricultural, animal, and forestry components. Leading feedstocks are corn and wheat starches, vegetable oils, rubber, animal-based proteins, gelatin, lignin, and mussels. Specialty natural adhesives are derived from highly refined starches. Synthetic adhesives are primarily derived from petrochemicals and include thermoplastics, thermosets, bitumens, and elastomeric adhesives. The thermoplastics sector is the largest sector by volume, while the elastomerics sector is highest in value of the synthetic adhesives.

The 12.8-billion-pound U.S. adhesives market was valued at $6.5 billion in 1995. In the last decade, overall adhesive

Figure 2
Adhesives Production by Major Class in 1995 1/



1/ In 1995, the estimated production and use of natural and synthetic adhesives was 12.8 billion pounds.
Source: Irshad Ahmed, Booz-Allen and Hamilton, Inc., McLean, Virginia, July 1996.

growth averaged 2 percent per year, by volume. The recession of 1990 dampened adhesive use, but the demand for natural adhesives has been growing steadily since late 1992. In 1995, the overall demand for adhesives grew 3.1 percent, and is projected to grow at 3.3 percent annually through 2000. Natural adhesives are expected to exceed this average and grow over 3.8 percent annually through 2000, higher than the rates projected for bitumens and elastomerics. Certain synthetic subcategories, catering to niche markets, may also see above average growth.

During late 1980's, certain synthetic subcategories saw growth several times the average, notably hot melt, hot melt pressure-sensitive, acrylic pressure-sensitive, polyvinyl acetate, cyanoacrylate, anaerobic, and radiation-curable adhesives. However, their growth rates have suffered in the 1990's. Environmental regulations restricting the use of certain synthetic adhesives, product-quality improvements, green-product reformulation, and identification of new applications, combined with overall growth in the U.S. economy in recent years, are some of the key factors responsible for the recent and projected growth for natural adhesives. This year's high corn prices, however, have dampened the demand for many starch-based adhesives. High-volume, low-value grades may see no or slight market growth until prices become competitive with other substitutes. High-value, refined, starch-based naturals may not be affected by higher corn prices.

Certain important categories of synthetics, particularly thermoplastics, are expected to shrink over the next 5 years, while some specific naturals, especially protein-based adhesives, will probably grow at twice the average. Part of this change is based on the industry's response to environmental regulations. For example, because of Clean Air Act regulations limiting emissions of volatile organic compounds, solvent-based adhesives are being displaced with refined naturals and other specialized synthetic elastomerics in such fields as pressure sensitive, construction, and automotive applications.

Robotics are an increasingly popular means of applying adhesives in assembly line production. These automated systems exhibit a technical preference for natural adhesives due to easy equipment cleaning and flow characteristics. Higher engineered applications, such as the replacement of mechanical fasteners, will also contribute to the overall growth of adhesive markets. In foundry applications, demand for natural adhesives (binders) is expected to grow at 2.8 percent annually to 134 million pounds in 1997.

Environmental concerns have spurred the use of natural adhesives that have better biodegradability profiles than their synthetic counterparts. The success of starch-based adhesives in the packaging industry is directly associated with the solid-waste disposal problems faced by petroleum-based films. Recycling operations have spurred the use of starch-based adhesives in paper cartons, bottle labels, stationery, and some interior plywood fabrications.

Starch-based adhesives are the largest segment of the natural-adhesives market. In 1995, approximately 60 percent of the 4 billion pounds of natural adhesives produced and consumed in the United States were derived from starch, primarily corn and wheat starch. These 2.4 billion pounds of starch required roughly 73 million bushels of corn equivalent. National Starch & Chemical Company is one of the leading starch-based adhesives companies in the United States. It has led the way in developing and introducing a number of starch-based adhesives, including the Kor-Lok and Duro-Lok lines of adhesives. It is estimated that there are over 100 different formulations of starch-based adhesives currently on the market. Starch-based adhesives are less expensive then other natural and synthetic adhesives and range in price between 50 cents and $2.50 per pound. Almost all natural adhesives are priced under $8.00 per pound.

Another type of natural adhesive is animal glue. It is produced by the hydrolysis of the protein collagen from the skins, hides, and bones gathered from slaughterhouses. The glue's diverse applications in paper, glass, abrasives, matches, and metal refining maintain its commercial position in the face of highly competitive synthetic materials. Besides being used directly as an adhesive, animal glue is also an additive in a wide range of adhesive and flocculating formulations.

New Research and Development May Lead to Future Growth

Significant research and development have been underway since the early 1980's to design and develop natural adhesives with specific functional properties. For example, at least three USDA laboratories are engaged in developing natural adhesives with better water resistance properties. Some of the latest natural adhesives under investigation are based on protein, fiber, and oil from corn, wheat, soybeans, and mussels.

Although soy proteins have been used in paints and coatings for many years for their coagulation properties, only recently have commercially viable adhesives with superior application properties been developed. Soy-based wood adhesives are the first alternative adhesives likely to capture significant market share. Mussel protein-based adhesives are already reaching commercial significance, with great potential in medical and industrial applications.

While new categories of natural adhesives are being developed, existing products are being improved. The outlook for natural adhesives in most application areas is bright through the turn of the century as environmental laws continue to regulate the use of synthetics. Efforts by private industry and USDA laboratories promise to further expand the number of natural adhesives and their market share. [*Industrial uses of corn*: Allen Baker, ERS, (202) 219-0360, albaker@econ.ag.gov. *Ethanol*: John McClelland, ERS/OENU, (202) 501-6631, jmcclell@econ.ag.gov. *Starch-based loose fill*: Paul Tatarka, ARS, (309) 681-6428, tatarkpd@ncaur1.ncaur.gov, and Charles Plummer, ERS, (202) 219-0717, cplummer@econ.ag.gov. *Adhesives*: Irshad Ahmed, Booz-Allen & Hamilton, (703) 917-2060, 71332.3160@compuserve.com.]

1. *Modern Plastics*, Vol. 73, No. 1, January 1996.

2. *Plastics News*, Vol. 8, March 25, 1996.

Crambe, Industrial Rapeseed, and Tung Provide Valuable Oils

In 1996, crambe is again being grown commercially, while industrial rapeseed acreage is down from previous years. Tung oil is being produced in the United States for the first time since 1973. Glycerine markets remain tight, as demand continues to outpace supply. Biodiesel commercialization faces a number of regulatory and market challenges in the United States.

Crambe Again in Commercial Production

The American Renewable Oilseed Association (AROA), an organization of crambe growers, contracted with 145 farmers in 1996 to grow 22,000 acres of crambe. No commercial acreage was planted in 1995 because much of the crambe oil produced in 1994 had not been sold prior to spring planting. Commercial crambe production began in North Dakota in 1990, and U.S. acreage peaked in 1993 at 57,683 acres (table 4). (See the June 1993 and the September 1995 issues of this report for more information on crambe supply and uses.)

All of the 1996 acreage is in North Dakota. As of mid-July, about 19,000 acres were in good to excellent condition. There is no predetermined contract price this year, but producers are likely to receive between 11.5 and 12 cents per pound of seed harvested. The crop will be toll processed by Archer Daniels Midland at its Enderlin, North Dakota, oilseed crushing plant. AROA has contracted with Witco Corporation, headquartered in Greenwich, Connecticut, to buy the crambe oil and will market the crambe meal to feed manufacturers for beef finishing rations.

AROA has set up a separate steering committee and business to develop a production, processing, and marketing infrastructure for novel oilseeds in the Northern Great Plains. The grower-owned company, AgGrow Oils, plans to offer stock to growers this December, construct a 200-ton-per-day crushing facility in 1997, and begin operation with the 1997 crop. Negotiations are underway that include contracting for 30,000 to 60,000 acres of crambe annually and other novel oilseeds such as high-oleic sunflower and safflower, flax, and possibly specialty canolas.

Table 4--Crambe acreage, United States, 1990-96 1/

Year	Planted area	Yield 2/	Production
	Acres	Pounds/acre	1,000 pounds
1990	2,359 3/	988	2,330 4/
1991	4,475 3/	1,153	5,160 4/
1992	23,204 5/	1,057	24,538 4/
1993	57,683 5/	972	56,090
1994	43,925 3/	1,350	59,200 6/
1995	400 7/	N.A.	N.A.
1996	22,000 3/	N.A.	N.A.

N.A. = Not available. 1/ Commercial acreage. 2/ North Dakota only. 3/ Contracted acreage. 4/ Net crop crushed. 5/ Acreage certified by the Farm Service Agency. 6/ Estimated. 7/ Acreage planted in 1995 was for seed production only.

Source: North Dakota State University.

U.S. Industrial Rapeseed Production Declines

Like crambe oil, industrial rapeseed oil contains high amounts of erucic acid. To meet industry requirements, industrial rapeseed oil must contain at least 45 percent erucic acid. In contrast, canola and other special types of rapeseed, such as high-lauric canola, have been bred or genetically engineered to contain different fatty acids in their oils. Canola oil is used for edible consumption and, according to Food and Drug Administration standards, must contain less than 2 percent erucic acid. Canola is the name generally applied to rapeseed that has low amounts of erucic acid in its oil and low levels of glucosinolates in its meal.

Cross pollination can occur if industrial rapeseed and canola are planted in adjacent fields, resulting in an oil with an intermediate erucic acid content that would be useless for either application. Visually, the seeds of the two types are identical; only testing can differentiate their characteristics. In the Pacific Northwest, where both types are grown, a couple of States have designated production regions to address the cross-pollination issue. Idaho established six production areas in 1986 and Washington State finalized rules and regulations for 12 production districts in 1988.

Industrial rapeseed has been grown in the Pacific Northwest for over 40 years. It was also produced in the South during the late 1980's and early 1990's. Harvested acreage of industrial rapeseed has declined from 19,400 acres in 1987/88 to 2,400 in 1995/96 (table 5). During the same period, domestic production has dropped from 22 million pounds to an estimated 3 million pounds.

In the Pacific Northwest, industrial rapeseed is produced for birdseed and oil. Historically, birdseed has accounted for at least 50 percent of production, according to Andrew Thostenson, a former merchandiser with Spectrum Crop Development, a canola and rapeseed merchandizing firm in Clarkston, Washington. After becoming familiar with canola, birdseed manufacturers now buy either industrial rapeseed or canola, whichever is cheaper.

The only known U.S. crusher of industrial rapeseed is Koch Agricultural Services of Great Falls, Montana. According to Steve Chambers, a marketing manager for the company, Koch contracts for seed and buys it on the open market. In addition, unprocessed seed is exported to Japan, where it is crushed and the oil used as lubricants in the steel manufacturing industry and the meal used as fertilizer.

Table 5—Industrial rapeseed, acreage planted, harvested, yield, production, and value, United States, 1987-95

Year	Planted	Harvested	Yield	Production	Value
	--1,000 acres--		Bushels per acre	1,000 pounds	Million dollars
1987	20.0	19.4	22.7	21,981	N.A.
1988	13.5	13.1	24.1	15,822	N.A.
1989	14.0	13.6	28.2	19,143	2.01
1990	15.0	14.6	31.2	22,717	2.33
1991	18.2	15.6	20.7	16,146	1.63
1992	12.0	9.8	29.5	14,455	1.45
1993	7.2	6.1	24.4	7,442	0.76
1994 1/	7.4	6.7	37.6	12,596	1.29
1995 2/	2.5	2.4	25.1	3,012	0.38

N.A. = Not available. 1/ Preliminary. 2/ Forecast.

The Market for Erucic-Acid Oils Remains Tight

Charles Leonard, an oleochemical industry expert, estimates world consumption of high-erucic-acid oils for industrial applications at about 125 million pounds per year, with the United States accounting for about 35 million pounds. This is up from a 1991 industry estimate of 25 to 30 million pounds for the U.S. share. Other major industrial users are Europe and Japan.

Two 1996 articles in the *Chemical Marketing Reporter*, quoting industry sources, estimate the U.S. supply of industrial rapeseed oil at about 5 million pounds of domestic production and around 25 to 30 million pounds shipped in from Canada and Europe (*1*, *2*). This is similar to USDA estimates of industrial-rapeseed-oil production and imports for the late 1980's and early 1990's (table 19). However, according to USDA figures, U.S. rapeseed oil production has declined from 5.7 million pounds in 1991/92 to an estimated 836,000 pounds in 1995/96, while imports have averaged 9.8 million pounds during the same period.

Although no data are available from industry sources or USDA on U.S. crambe-oil production, crambe oil reportedly gained acceptance in the U.S. high-erucic-acid market in the early 1990's when Humko Chemical, a division of Witco Corporation, began relying on it as a domestic source of erucic acid. Humko currently uses both industrial rapeseed and crambe oils (*4*), but supplies of crambe oil are reported as limited.

World supplies of high-erucic acid oils have tightened in the last few years as older rapeseed varieties have been replaced with canola types. For example, Poland and the former East Germany historically have been heavy producers of industrial rapeseed oil because much was used for edible purposes. However, since the breakup of the Eastern Bloc, industrial rapeseed has yielded to canola because industrial rapeseed oil cannot be sold to European Union countries for edible purposes. Erucic acid-containing rapeseed varieties are now considered specialty crops in Canada and Europe. China, Russia, and India, however, still use high-erucic acid rapeseed oil for human consumption.

World supplies of industrial rapeseed oil are expected to remain tight. Although Canadian production is fairly stable, European production is below expectations again this year. According to a spokesman for Croda Universal, Inc., which is headquartered in the United Kingdom, the 1996 European harvest of industrial rapeseed will be 1,000 hectares short of what is needed (*1*). The U.S. market for high-erucic-acid oils will likely be served mostly by domestic production and imports from Canada. Calgene Chemical, a subsidiary of Calgene, Inc., of Davis, California, has an agreement with CanAmera Foods of Oakville, Ontario (North America's largest rapeseed processor) to distribute some of CanAmera's industrial rapeseed oil in the United States.

Prices for erucic-acid oils have increased as supplies have tightened (*1*, *2*). Higher world prices have been felt in erucic-acid product markets. Three producers of erucamide—Witco Corporation, Croda Universal, Inc., and Akzo Nobel Chemicals, Inc.—raised the prices of their erucamide products by 20 cents per pound in April and May 1995 due in part to high prices of high-erucic-acid oils. Because of current high prices and the prospects of continued tight supplies, the companies increased their erucamide prices again in May and June 1996, Akzo by 8 cents per pound and Witco and Croda by 25 cents per pound. While U.S.-based Witco uses both crambe and industrial rapeseed oils, the other two manufacturers use only industrial rapeseed oil.

High-Erucic-Acid Oils Have Traditional And Emerging Uses

The primary market for high-erucic-acid oils is erucamide. Plastic-film manufacturers have used erucamide for decades in bread wrappers and garbage bags. It lubricates the extruding machine during manufacture of thin plastic films. After processing, the erucamide migrates to the surface of the films and keeps them from clinging together. Two cheaper amides, stearamide and oleamide, cannot individually provide the critical properties that erucamide does. Therefore, erucamide is preferred, even at about twice the price.

Charles Leonard estimates that 48 million pounds of high-erucic-acid oils are used worldwide in making about 15 million pounds of erucamide per year (table 6). Erucamide is sold by a half dozen oleochemical producers in the United States, Europe, and Asia. Witco is the largest worldwide producer and marketer, supplying product from its Memphis, Tennessee, production facility. Leonard estimates that erucamide market growth roughly parallels the growth of polyolefin film sales, which in recent years has ranged from 4 to 6 percent per year.

Table 6–Estimated worldwide use of high-erucic-acid oils for industrial applications

Derivative	Application	Volume of oil used	Volume of derivative produced
		1,000 pounds	
Erucamide	Slip agent	48,000	15,000
Erucyl alcohol	Emollient	30,000	10,000
Various fatty nitrogen derivatives	Hair care and textile softening	18,000	6,000
Behenyl alcohol	Pour point depressant	18,000	6,000
Esters and others	Lubricants	6,000	4,000-5,000
Gyceryl tribehenate	Food emulsifier	2,500-3,000	2,500-3,000
Silver behenate	Photography	~750	~250
Total		123,250-123,750	43,750-45,250

Source: Charles Leonard, "Sources and Commercial Applications of High-Erucic Vegetable Oils," Lipid Technology, July/August 1994.

Cationic surfactants that function as active ingredients in personal-care products, laundry softeners, and other household products appear to be an up-and-coming use for high-erucic-acid oils. Some companies in Japan and the United States are using cationic surfactants derived from 22-carbon fatty acids, such as those found in rapeseed, crambe, and meadowfoam oils, as the active ingredient in hair conditioners. At least two U.S. companies are doing research in this area. An estimated 18 million pounds of high-erucic-acid oils are used worldwide to manufacture roughly 6 million pounds of cationic surfactants.

Because rapeseed and crambe oils have a high degree of lubricity, they also are used either directly as lubricants or in lubricant formulations. They are used as spinning lubricants in the textile, steel, and shipping industries; as cutting, metal-forming, rolling, fabricating, and drilling oils; and as marine lubes. For example, Calgene Chemical offers a line of erucic-acid esters to the textile and automotive fluids industries. International Lubricants, Inc., of Seattle, Washington, sells erucic-acid-oil-based automatic transmission fluid additives, cutting oils, hydraulic oils, and power steering fluids. The transmission fluid additives are currently used by five European automobile manufacturers and U.S. transmission repair shops, and are newly available in retail auto parts stores.

One of the selling points of the erucic-acid-oil products offered by International Lubricants is their enhanced biodegradability compared to their petroleum-based counterparts. Thus, they are said to be more environmentally friendly. Several companies are reportedly in the market for industrial rapeseed and canola oils for lubricant applications because of their environmental attributes, which has caused a recent increase in demand (*2*).

Another use of erucic-acid oils in response to environmental concerns is in the production of concrete mold-release agents. Leahy-Wolf Company of Franklin Park, Illinois, has developed and patented a biodegradable concrete-release agent based on industrial rapeseed oil, and is marketing it through U.S. distributors. Construction companies and precasters of concrete structures, such as sewer pipes, vaults, and bunkers, coat their molds and forms with release agents to facilitate the release of the hardened concrete. Often these compounds, which are traditionally petroleum-based, leach out of the mold or concrete and end up in the groundwater. Construction firms and precasters have had to modify their operations, however, to meet increasingly strict State and local regulations that limit the release of petroleum-based chemicals into the environment.

Tung Oil Production Begins Again In the United States

Tung oil, a nonedible vegetable oil, is scheduled to be produced again in the United States beginning in December 1996. The sole U.S. producer will be American Tung Oil Corporation (ATO) of Lumberton, Mississippi. ATO was created 4 years ago by Blake Hanson of Industrial Oil Products (IOP) of Woodbury, New York, to revive domestic production of tung oil, which has not occurred since March 1973. IOP is the largest supplier of tung oil in the Western Hemisphere.

Tung oil, produced from the fruit (nut) of the tung tree, contains mainly eleostearic fatty acid, with smaller amounts of oleic, linoleic, and palmitic fatty acids. Tung oil's physical and chemical properties make it useful as a protective coating, solvent, and/or drying agent in various paints, varnishes, lacquers, resins, fiberboard, concrete sealers, electronic circuit boards, and printing inks. Its superior drying properties allow it to be sold at a price premium compared to other vegetable drying oils such as linseed oil (tables 37 and 40). Various new applications for tung oil and its byproducts also are being developed for use in products such as cosmetics, insecticides, and lubricants.

Tung oil is produced commercially mostly in subtropical regions, primarily in China and South America. Tung oil production is small compared with that of many other vegetable oils. Estimated world production averages 50,000 metric tons a year. Major producers include China (about 42,000 metric tons), Paraguay (about 4,000 metric tons), Argentina (about 3,000 metric tons), and Brazil (about 1,000 tons) (*3*).

The world supply of tung oil can be very volatile, as tung orchards can be greatly affected by adverse weather conditions and by age of the orchards. Though hearty, fast growing, and naturally resistant to disease and insects (tung trees require no fungicides or pesticides), tung trees are very sensitive to temperature levels during fruit-set. There is also some concern that aging orchards in South America may be losing productivity. In addition, Brazil produces primarily for domestic consumption and China uses as much as 25,000 metric tons of oil per year (*3*). A poor

Table 7--U.S. imports of tung oil and its fractions, volume and value, by country, 1991-95

Country	1991	1992	1993	1994	1995
			Metric tons		
Argentina	2,380	3,455	2,137	1,627	2,797
Paraguay	3,085	823	1,557	2,526	1,235
China	179	318	546	1,206	379
Brazil	0	400	0	0	0
Other	0	0	30	42	16
Total	5,645	4,996	4,270	5,401	4,427
			Thousand dollars		
Argentina	2,584	6,828	4,175	1,881	2,739
Paraguay	3,051	825	2,801	2,438	1,044
China	206	709	926	1,201	382
Brazil	0	525	0	0	0
Other	0	0	70	43	18
Total	5,841	8,888	7,971	5,563	4,182

Source: U.S. Department of Commerce, Bureau of the Census.

crop in any of the major producing countries often leads to volatile tung oil prices.

The current U.S. tung oil market is supplied largely by Argentina and Paraguay. During 1991-95, 50 percent of U.S. imports of tung oil came from Argentina, another 37 percent from Paraguay, and 11 percent from China (table 7). Small South American crops in 1991/92 and 1992/93 led to extremely high tung oil prices in the United States from mid-1992 through most of 1993 (table 40). Good crops in South America and China in 1993/94 helped prices decline in 1994. Decreased demand from Japan and Europe in 1994 and 1995 helped keep U.S. tung oil prices down, despite smaller crops the last two seasons.

However, U.S. tung oil prices have increased slightly this summer, and may rise even further, as South America and China are anticipating relatively small crops again this season. In addition, a lower supply of Chinese tung oil and renewed Japanese demand due to a strengthening economy are likely to put more upward pressure on prices for South American tung oil. How far prices will rise remains to be seen, but the market's continued volatility will likely encourage some companies to use other natural and synthetic alternatives in their product formulations.

Tung Production Is Centered in Mississippi

ATO is confident its revitalization of domestic production will help stabilize tung oil supply and prices. The company is currently planting its initial goal of 5,000 acres of tung trees, 500 acres of which will be company owned, and the rest contracted with individual growers. Current production of tung nuts is from several hundred acres of 3- to 4-year-old trees in southern Mississippi, although ATO is open to contracting with growers in other parts of the U.S. production region (a 100-mile wide area along the Gulf Coast extending from north central Florida into eastern Texas). The oil will be extracted at ATO's Tung Ridge Ranch mill near Poplarville, Mississippi, and will be distributed by IOP.

Blake Hanson, president of IOP, projects U.S. production for 1996 to be about 50,000 pounds of oil, which will have little impact on world markets. However, Mr. Hanson notes that as trees reach production maturity in about 4 to 5 years (when they will be 7 to 8 years old), the United States will be a significant producer of tung oil. He projects that in 5 years, U.S. production will be about 2 million pounds of oil. In 8 years, if all 5,000 acres are planted and producing, production could be over 4 million pounds. These trees could sustain commercial production for about 25 years, unless destroyed by natural disaster.

Prior U.S. production of tung oil occurred between the late 1930's and 1972, peaking in 1958 at 44.8 million pounds. Indicative of the tung oil industry, production during this period varied greatly from year to year, due primarily to the crop's natural bearing cycle and late frosts during budding. Weather will still be an important factor in this current production effort. However, higher fruit yields than were realized in previous decades are anticipated due to the use of heavy bearing varieties and improved farming methods. Harvesting costs will be reduced by mechanical harvesting, which is not used internationally and was not employed in the United States until the late 1960's. In addition, ATO plans to store surplus tung oil during years of over-production in an attempt to stabilize market prices during years of under-production. Under proper conditions, tung oil can be stored for several years.

Tung Oil Market Has Changed

The U.S. market for tung oil has changed dramatically during the past half-century. U.S. industrial use of tung oil peaked in 1947 at 130.4 million pounds, with over 75 percent used by the paint and varnish industry, and about 10 percent used by the resins industry. However, in the late 1940's, as the protective coatings industries shifted to lower cost substitutes, including synthetics and other oils, domestic consumption of tung oil declined dramatically. By 1961, domestic use had fallen to around 35.9 million pounds, with 73 percent consumed by the paint and varnish industry and 15 percent by the resins industry.

A general shift from the use of vegetable oil-based paints, which often require petrochemical solvents to reduce paint viscosity, in favor of water-based latex paints since the 1960's, contributed to a further decline in the use of tung oil. In 1994, domestic use was estimated at 9.3 million pounds, with 71 percent consumed by the resins and plastics industry, and 13 percent by the paint and varnish industry (table 30). The 1995 estimate for domestic use of tung oil is 20.2 million pounds, but this, according to industry sources, is likely overstated. One industry source estimates current tung oil use at around 10 million pounds, broken down as follows: 40 percent in paints, varnishes, and wood coatings; 40 percent in inks and overprint varnishes for graphic arts; 14 percent in fiberboard and other building materials; and 6 percent in miscellaneous items like caulk, concrete sealers, and brakepads (*3*).

Current and future uses of tung oil depend on several factors, including various regulations in the Clean Air Act Amendments of 1990 (CAAA) that require coatings manufacturers to reduce volatile organic compounds (VOC's) in their formulations. Petrochemicals such as toluene, xylene, methyl ethyl ketone, and methyl isobutyl ketone must be

eliminated entirely. Chlorinated solvents must be removed from formulations because of their ozone-damaging potential. Because of these regulations, many companies are formulating new products, a number of which use tung oil because of its good drying ability and inherent solvency. However, these regulations have also caused the phaseout of some older tung-oil-containing products that include petrochemical solvents, which contain VOC's. Therefore, the net effects of CAAA regulations for the coatings industries will continue to play a major role in tung oil consumption. (For more information on VOC's and solvent replacements, see the fats and oils section of the June 1994 issue of this report).

In addition to air quality regulations, future uses of tung oil are likely to depend upon market stabilization, price reduction, and the development of new uses and new modified-tung oil products. Lower prices and the success of these new products will be vital to increasing the demand for tung oil.

Glycerine Uses Continue To Expand

Glycerine is a byproduct of producing soaps, fatty acids, and fatty esters from the triglycerides in vegetable oils and animal fats. Primary sources of glycerine include tallow, palm kernel oil, and coconut oil. Dow Chemical is presently the only U.S. manufacturer producing synthetic glycerine from petrochemicals.

Although the terms glycerine, glycerin, and glycerol often are used interchangeably, subtle differences in their definitions do exist. Glycerine is the commonly used commercial name in the United States for products whose principal component is glycerol. Glycerin refers to purified commercial products containing 95 percent or more of glycerol. Glycerol is the chemical compound 1,2,3-propanetriol.

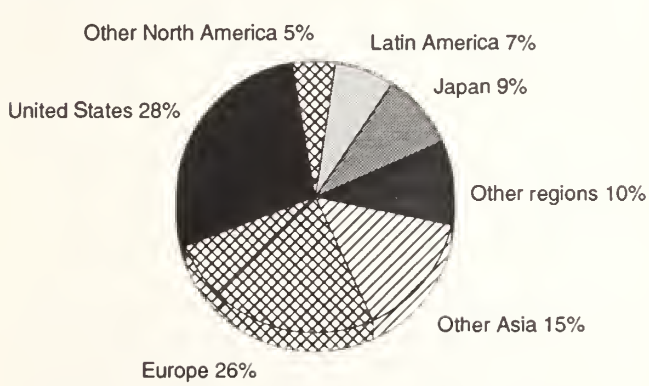
Worldwide production and consumption of glycerine is estimated at 1.5 billion pounds in 1995, up 10 percent from a year earlier. Europe and the United States account for over half of the consumption volume (figure 3). The supply of natural glycerine is directly related to fatty-acid and fatty-ester production. More sources of byproduct glycerine have been identified in recent years as uses for vegetable oils have increased, including processes for manufacturing biodiesel, fat substitutes, and polyols. In Europe, an estimated 100 million pounds of glycerine is currently produced in biodiesel production plants.

In 1995, the United States had an estimated glycerine production capacity of 522.5 million pounds. Roughly 25 percent of that is synthetic glycerine. Procter & Gamble and Dow Chemical are the two largest U.S. producers. In the United States, eight natural glycerine producers, including Procter & Gamble, currently have 15 production plants in operation. Dow has one synthetic glycerine plant.

Glycerine is used in over 1,500 applications and end products. It has an extensive list of traditional uses that include drugs, cosmetics, resins, polymers, explosives, toothpaste, tobacco processing, paints, paper manufacturing, lubricants, textiles, and rubber (see the December 1993 issue of this report for more information). Pharmaceuticals, toothpaste, and personal-care products were major uses in 1995 (figure 4), and more applications are being developed all the time. For example, because of its environmentally friendly characteristics, glycerine has potential in new-generation fabric softeners, deicing fluids, and drilling fluids.

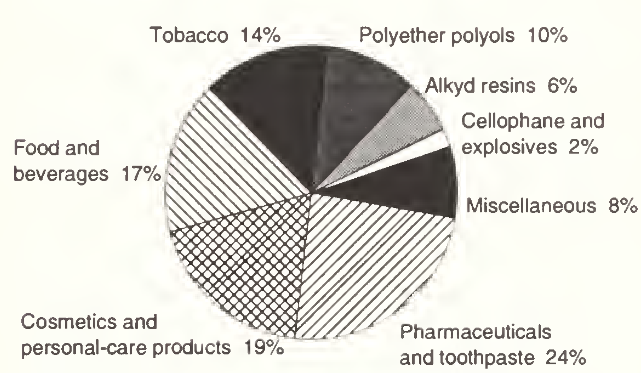
The glycerine market has been tight since 1992. While world production has increased, rising demand continues to outpace supply. Glycerine competes with sorbitol and propylene glycol in food, beverage, and tobacco applications, but these and other glycerine substitutes may not be readily accepted by consumers because of their taste. Although tight supply conditions are expected to continue, declining cellophane and explosive use will compensate for some of the projected growth in newly identified applications, such as fabric softeners, sports drinks, and deicing fluids.

Figure 3
Estimated World Consumption of Glycerine, By Country, 1995 1/



1/ Worldwide glycerine production and consumption is estimated at 1.5 billion pounds in 1995.
Source: Irshad Ahmed, Booz-Allen and Hamilton Inc., McLean, Virginia, July 1996.

Figure 4
Estimated End Uses of Glycerine In the United States, 1995 1/



1/ U.S. glycerine production capacity is estimated at 522.5 million pounds in 1995.
Source: Irshad Ahmed, Booz-Allen & Hamilton Inc., McLean, Virginia, July 1996.

Glycerine prices fluctuate widely, depending on supply and demand factors. Historically, glycerine prices have ranged from 51 cents to $1.08 per pound. Current prices are between $1.05 and $1.08 per pound. High 1996 prices are due to a worldwide shortage of glycerine estimated at roughly 100 million pounds. Demand is strong because of new applications, an unwillingness on the part of end-product manufacturers to switch to substitutes, and environmental pressures to enhance end-product biodegradability.

To satisfy the rising demand for glycerine, producers are boosting capacity by an estimated 50 million pounds through expansion and debottlenecking of existing facilities. Henkel Corporation, which is headquartered in Germany, is investing $60 million to add 10 to 20 percent to its worldwide glycerine capacity.

U.S. demand in 1995 is estimated at 420 million pounds. The market is expected to grow 3 to 4 percent per year through 2000, higher than its historical growth rate of 2 to 3 percent per year, due to a wide variety of newer applications and product lines. By the year 2000, demand is projected to reach 500 million pounds. Glycerine prices are expected to remain high because of continued increases in demand.

Fuel and Environmental Regulations Offer Challenges for Biodiesel

One potential source of glycerine in the United States is biodiesel. However, despite new market opportunities for alternative fuels created by CAAA and the Energy Policy Act of 1992 (EPACT), biodiesel commercialization still faces a number of regulatory and market barriers.

One challenge stems from EPACT's alternative-fuel, motor-fleet regulations that require Federal, State, and alternative fuel providers to increase their purchases of alternative-fueled vehicles. In a March 1996 final rule on the Alternative Fuel Transportation Program, the U.S. Department of Energy (DOE) concluded that neat (100 percent) biodiesel meets EPACT's criteria as an alternative fuel for this program (*5*). However, biodiesel is an expensive fuel and to lower its cost, potential users want to blend it with petroleum diesel. The most common blend used today is a mixture of 20-percent biodiesel and 80-percent petroleum diesel (B20). However, B20 vehicles have been disqualified from the Program based on the March 1996 final rule. In the absence of a special ruling on B20 or some other blend, it is unlikely that an immediate demand for biodiesel will be created through the Alternative Fuel Transportation Program. Biodiesel advocates are working with DOE to establish an appropriate blend level that will qualify as an alternative fuel.

Like most fuel producers, manufacturers of biodiesel and biodiesel blends have to meet CAAA fuel-property definitions and satisfy health-effect requirements. Hence, another regulatory hurdle stems from the U.S. Environmental Protection Agency's (EPA) current rule-making process of defining a standard diesel fuel. This definition will enable fuel manufacturers to determine whether their diesel fuels are substantially similar (sub-sim) to EPA's definition of diesel fuel in terms of chemical composition. When the final rule is implemented, most fuel manufacturers, including those of biodiesel and biodiesel blends, must either be able to prove that their fuels are sub-sim to the diesel standard or receive a waiver under CAAA Section 211(f). If fuel manufacturers are able to show that biodiesel has the same emission characteristics and the same engine degradation properties as EPA's definition of diesel fuel, they may be able to get a waiver for biodiesel. EPA expects to propose definitions for diesel fuel in December 1996, with an expected final rule in December 1997.

Biodiesel producers also have to overcome the potential public-health-effect data requirements under CAAA Section 211(b) and (c). These provisions require manufacturers to gather preliminary research data on their fuels to evaluate the potentially harmful human health effects of fuel emissions and submit this information to EPA by May 1997. Biodiesel analysts are currently conducting research that will help biodiesel comply with both the sub-sim and health-effect requirements. Negative findings from these data could delay commercialization and require the biodiesel industry to conduct a new round of expensive health-effect testing to address EPA concerns.

Another regulatory challenge for biodiesel relates to EPA's requirements on implementing particulate matter (PM) standards for pre-1994-model-year urban buses in areas with a 1980 population of more than 750,000. Finalized in 1993, the Urban Bus Retrofit Rebuild Program is designed to reduce PM exhaust emissions from older-model urban buses. Although the standards were to become effective when engines are rebuilt or replaced after January 1, 1995, EPA delayed enforcement for 1 year.

EPA has developed two compliance options to provide some flexibility to bus operators in meeting the new PM standards. The standards in both options are based on what PM reductions can be achieved by equipment certified by EPA. The first option requires an operator to install certified PM-reduction equipment on each of their buses when bus engines are rebuilt or replaced. (An urban bus engine generally undergoes two or three rebuilds during its 15-year lifetime.) The second option requires that PM levels for the entire bus fleet be below a yearly average target level at the beginning of each year. This target level can be calculated by urban bus operators through a computer program provided by EPA. Average target levels will vary by engine age and PM-reduction requirements for the various engine types within the fleet.

To date, five technologies in the form of rebuild kits and/or catalytic converters have been certified by EPA for the Urban Bus Retrofit Rebuild Program. In June 1995, Twin Rivers Technologies, a Massachusetts-based company, submitted a certification package to EPA different from the five technologies. This package aims to lower PM in some bus engines through the combined use of B20 and a catalytic converter. Even with EPA certification, the B20 package still faces an economic challenge, because under the first compliance option, the certified rebuild kits and catalytic converters are cheaper to use than the B20 package. Biodiesel may have a better opportunity under the second option, depending on how the B20 package affects fleet operators' average PM target levels.

Additional Research Is Needed

Research is needed to help biodiesel comply with government regulations, including exploring its environmental and health benefits and economic feasibility. USDA, DOE, and the National Biodiesel Board (NBB) have been working together to investigate these topics. For example, representatives from these organizations, along with university and other researchers, recently attended a biodiesel workshop at Mammoth Hot Springs, Wyoming, May 21-22, 1996. DOE, through its Pacific Northwest and Alaska Regional Bioenergy Program, and the University of Idaho's National Center for Advanced Transportation Technology sponsored the event, entitled Commercialization of Biodiesel: Environmental and Health Effects Workshop. The workshop's purpose was to assess the health and environmental effects associated with emissions from compression ignition engines and to identify the benefits to be gained by using biodiesel.

Workshop participants agreed that, when compared to petroleum diesel, neat biodiesel generally offers the following known environmental and health benefits: biodegradability; reductions in soot, greenhouse gases, and some emission levels; and a positive energy balance. Several other benefits were identified, such as reduced toxicity and lower amounts of ozone precursors and mutagenic and carcinogenic compounds. However, additional data are needed to verify these potential benefits and how they change when blended with petroleum diesel. Workshop organizers hope to use these known and potential environmental and health benefits to help meet CAAA health-effect data requirements and as an education campaign to boost biodiesel commercialization.

An important opportunity to show biodiesel's net environmental benefits will be an analysis of biodiesel's life-cycle. The main purpose of this joint USDA-DOE study is to compare the environmental effects of biodiesel versus petroleum diesel. Life-cycle analysis accounts for all production activities and raw materials involved in producing a product. For example, with biodiesel, the analysis begins with assessing the environmental effects of growing soybeans, including the production of seed, fertilizer, and other inputs used on the farm. After the inputs aspect is analyzed, the environmental effects are then examined through the product's manufacturing, followed by consumption, and finally the waste stage (recycling or disposal). A final report is expected before the end of the year.
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1. Chapman, Peter. "HEAR Oil Supply Crimp Affecting Erucic Users." *Chemical Marketing Reporter*. Schnell Publishing Company, New York, NY, May 6, 1996, p. 10.

2. Dolack, Pete. "HEAR Oil Prices Higher Due to Supply Tightness." *Chemical Marketing Reporter.* Schnell Publishing Company, New York, NY, March 4, 1996, p. 10.

3. Hanson, Blake, President, Industrial Oil Products, Woodbury, NY. Personal Communication, July 10, 1996.

4. Santos, William. "Crambe Oil Makes Moves Into Rape seed Oil Territory." *Chemical Marketing Reporter*. Schnell Publishing Company, New York, NY, April 1, 1996, p. 10.

5. U.S. Department of Energy. "Alternative Fuel Transportation Program." *Federal Register*, Vol. 61 No. 51, March 14, 1996, pp. 10,629-30.

Hesperaloe Has Properties That Interest Papermakers

The University of Arizona has been working with several companies in the pulp and paper industry to develop Hesperaloe *as a new source of fibers for papermaking.* Hesperaloe *fibers are unusually long and thin, similar to those of abaca and sisal. Such nonwood fibers have important uses in high-value specialty papers. While abaca and sisal fibers are imported,* Hesperaloe *could be produced in the southwestern United States.*

Most papermakers in the United States, Canada, and Europe use trees as their source of fibers. In the pulping process, the wood is broken down, either chemically or mechanically, into individual fiber cells that are then suspended in an aqueous slurry and reformed into sheets on high-speed papermaking machines. Evergreen conifers (softwoods), such as pine, spruce, and Douglas fir, produce comparatively long fiber cells that form strong paper. Broad-leaved trees (hardwoods), like poplar and aspen, have shorter, broader cells that produce a smoother paper with less strength. Many papers, such as newsprint, are a mixture of softwood and hardwood pulps. Because the stronger softwood pulps command a higher price than hardwood pulps, papermakers blend these pulps to optimize paper quality while minimizing their use of higher cost fibers.

Nonwood fibers, such as cereal straws, bamboo, and sugarcane bagasse, are also used in the pulp and paper industry. In 1993, world nonwood pulping capacity was 21 million metric tons, 10.6 percent of world paper pulping capacity (*1*). Nonwood fibers are an important source of papermaking materials in developing countries that have limited forest resources. China and India account for about 80 percent of the world's nonwood pulping capacity.

There have been efforts in the United States over the past 30 years to develop kenaf, an annual fiber crop, as a nonwood fiber for papermaking, and more recent work in Europe has emphasized fiber hemp. Given that almost any plant is suitable for making some type of paper, a new crop developed specifically for papermaking must have significant advantages in both quality and price to justify the commercialization effort.

Hesperaloe *a Possibility*

The University of Arizona has been working with several companies in the pulp and paper industry to develop two species of *Hesperaloe (H. funifera* and *H. nocturna*, desert plants native to northern Mexico) as a new source of fibers for papermaking. This 10-year project is about to move from the exploratory research and development stage toward full-scale commercialization. [1]

The greatest market opportunity for *Hesperaloe* fibers may be as a blend for strengthening various grades of paper (*2*), such as recycled paper. Fiber cells lose considerable strength in the deinking and repulping processes. Some amount of virgin fiber, usually softwood, must be added to recycled fibers to provide strength. Using a nonwood fiber, such as *Hesperaloe*, in recycled papers could be an attractive feature to consumers.

The fiber cells of these *Hesperaloe* species are unusually long and thin (table 8). They range between 3 and 4 millimeters in length, comparable to the softwood fibers. However, they are much narrower, only 14 to 17 microns in width. The ratio of length to width, called the aspect ratio, is a good indicator of paper strength. This ratio for *Hesperaloe* is very high, about 240. In other words, *Hesperaloe* fibers combine the length of softwoods with the narrowness of straw fibers, an unusual property found only in abaca, sisal, and a few other specialty fibers.

Pulps with special properties, such as a high aspect ratio, command a relatively high price. Some specialty nonwood pulps cost two to four times that of softwood pulps (table 9). Abaca and sisal pulps, in particular, may cost $2,500 to $3,000 per metric ton. Both abaca and sisal are tropical crops that are harvested by hand and processed in small batch facilities, which account for the high cost of their fibers. Sisal production and processing, however, may change in the future if production is geared toward paper applications instead of twine and cordage.

Because of their high cost, use of abaca and sisal pulps is restricted to certain small specialty markets, such as tea bags, certain filters, and sausage skins (*2*), with stringent requirements for high strength and fine texture (*1*). Accord-

Table 8--Dimensions of papermaking fibers

Fiber	Mean length	Mean width	Length to width ratio
	Millimeters	Microns	
Abaca	6.00	20	300:1
Hesperaloe funifera	3.60	15	240:1
Sisal	3.03	17	180:1
Cotton linters	3.50	21	165:1
Kenaf bast fiber	2.74	20	135:1
Wheat straw	1.48	13	110:1
Softwoods	3.00	30	100:1
Jute	2.00	20	100:1
Hardwoods	1.25	25	50:1

Source for fibers other than Hesperaloe: Alfred M. Hurter, "Utilization of Annual Plants and Agricultural Residues for the Production of Pulp and Paper," Nonwood Plant Fiber Pulping Progress Report 19, TAPPI Press, Atlanta, Georgia, 1991.

[1] Some of the research was funded by USDA's Alternative Agricultural Research and Commercialization Corporation under Agreement 93AARC20030 and USDA's Cooperative State Research, Extension, and Education Service under Cooperative Agreement 94-COOP-1-0036.

Toble 9–Prices for different pulps, 1991

Pulp type	Price
	Dol./metric ton
Well-cleaned, bleoched nonwood fiber pulps 1/	$1,800-2,400
Not so well-cleaned, unbleoched nonwood fiber pulps 1/	$1,200-1,800
Speciol softwood pulps	$750-850
Normol softwood pulps	$550-750
Normal hordwood pulps	$450-550

1/ Abaca, sisal, flax, and hemp.

Source: Manfred Judt, "Non-Wood Plant Fibres, Will There Be a Come-Back in Paper-Making?," Industrial Craps and Products, Vol. 2 No 1, 1993, pp. 51-57.

ing to Census Bureau data, imports of raw or processed abaca fiber averaged 990 metric tons per year during 1989-94, while imports of raw or processed sisal fiber averaged 500 kilograms during the same period. Some imports of abaca and sisal cordage may also be used by the pulp and paper industry. Imports of abaca and sisal twine and cordage averaged 6,700 and 78,800 metric tons, respectively, during 1989-94.

The James River Corporation has investigated using *Hesperaloe* fibers in several types of paper. Its patent on the use of *Hesperaloe* in tissue and towel papers (*3*) provides some information on the performance of these fibers. With these types of sanitary papers, it is difficult to simultaneously improve both softness and strength. However, using *Hesperaloe* fibers in the blend enhances both strength and softness, while increasing bulk and absorbency. An unpublished study, conducted by the Herty Foundation of Savannah, Georgia, for the University of Arizona, compared papers made from *Hesperaloe* (unbleached hand sheets) with papers made from softwood kraft, abaca, and sisal. According to this study, the *Hesperaloe* papers had superior breaking length and burst index over a range of refining intensities. Thus, papers made from *Hesperaloe* fibers are as good as those made from high-cost, specialty pulps.

Hesperaloe *Production Is Under Investigation*

The compact growth habits of *Hesperaloe funifera* and *H. nocturna* suggest that they could be grown at a high stand density. These perennial plants are very water-efficient, and their leaves are spineless and thornless, which facilitates handling. All these traits suggest that *Hesperaloe* species might do well under irrigated production in the arid southwestern United States.

Test plantings of *Hesperaloe funifera* have been growing at Tucson, Arizona, for more than 8 years. Initial growth of transplanted stands was very slow, but high biomass yields were obtained after 5 years (table 10). Stands harvested at 5 years regrew to produce a second harvest after another 3 years. A third harvest may be possible after another 2 years, since each plant now consists of a larger base from which more regrowth can occur. It is unknown how many harvests could be made from a single stand before plants expand to fill the rows and interfere with machine operations. Larger plantings have been established recently at the Maricopa Agricultural Center at Maricopa, Arizona.

Because seeds of these species are extremely scarce, and because planted seeds are slow to germinate and emerge, commercial production of *Hesperaloe* will have to use transplants for stand establishment. Weed control will also

Toble 10--Biomoss production by Hesperaloe funifero

Stand density	First harvest (year 5)	Second harvest (yeor 8)
Plonts/ocre	Fresh weight metric tons/ocre	
2,750	43.4	41.5
5,500	68.2	71.3
11,000	97.8	99.7

be costly in the beginning, since *Hesperaloe* is not competitive during its first few years when growth rates are low.

Hesperaloe has a low-irrigation requirement because it possesses the crassulacean acid metabolism (CAM) pathway for photosynthesis. CAM plants take up carbon dioxide and transpire water at night rather than during the day, as is the case with most plants. Since the rate of transpiration is much lower during the night than during the day, CAM plants have a very high water-use efficiency. Grown throughout the year, *Hesperaloe* only requires about 24 inches of water annually. In comparison, wheat, which is grown in the winter in Arizona, requires about 36 inches of irrigation water and cotton, a summer crop, requires about 48 inches.

The projected crop cycle for *Hesperaloe* consists of stand establishment with transplants during year 1, first harvest at year 5, second harvest at year 8, and third harvest at year 10 or 11. Fresh-weight leaf yields from the three harvests obtained over the 10 or 11 years are projected to total about 250 metric tons per acre (based on a planting density of 8,700 plants per acre). For commercial production, flower stalks would be removed at an early stage of growth. The effects of this on subsequent leaf growth has yet to be investigated. Because dry fibrous raw material represents approximately 30 percent of the leaf fresh weight and pulp yield is 40 percent of the raw material, 1 acre of *Hesperaloe funifera* could probably produce sufficient biomass to yield 30 metric tons of pulp. This is equivalent to a 10- to 12-percent pulp yield based on the original fresh weight. Like abaca and sisal fibers, *Hesperaloe* fibers can be pulped by the kraft, soda, or sulfite processes (*2*, *3*).

In addition to its possible use in specialty papers, *Hesperaloe* could also potentially replace some softwood uses. For instance, in some applications, half as much sisal pulp can be used when substituted for softwood pulp (*2*), but market prices for sisal and softwood pulps do not favor such substitution. However, *Hesperaloe* pulp is superior to that of sisal and probably can be produced for less than twice the average price of softwood pulp. (Softwood pulp prices vary greatly in 3- to 5-year cycles.) This potential for substituting *Hesperaloe* pulp for softwood pulp would greatly expand its market opportunities beyond that of the premium specialty papers. Additional markets would be necessary to justify the development of a new fiber crop, given the small size of the specialty papers market.

Research on *Hesperaloe* will continue. Acreage at the Maricopa Agricultural Center is being expanded, primarily to increase seed production. The private sector is conducting pilot-scale pulping and papermaking trials. [Steven McLaughlin, University of Arizona, Office of Arid Lands Studies, (602) 621-8577, spmcl@ag.arizona.edu]

1. Atchison, Joseph E. "Nonwood Fiber Could Play Major Role in Future U.S. Papermaking Furnishes." *Pulp and Paper*, July 1995, pp. 125-31.

2. Hurter, Alfred. M. "Utilization of Annual Plants and Agricultural Residues for the Production of Pulp and Paper." *Nonwood Plant Fiber Pulping Progress Report 19*, TAPPI Press, Atlanta, GA, 1991.

3. Reeves, R.H., J.D. Plantikow, L.J. Smith, T.P. Oriaran, A.O. Awofeso, and G.L. Worry. "Soft High Strength Tissue Using Long-Low Coarseness *Hesperaloe* Fibers." U.S. Patent No. 5320710, 1994.

Wool Gaining Favor Outside of Apparel Industry

Traditionally, wool has been used in making worsted and woolen fabric for apparel and carpet, but wool's resiliency, absorbency, and flexibility have made it a popular input into other industries as well.

Wool fibers are mechanically processed to form yarns, threads, fabrics, and nonwovens, with various end uses. Apparel, upholstery, blankets, carpeting and carpet pads, windings for baseballs, felts for piano hammers, and fabric for billiard and gaming tables are just a few of the many products that are made out of wool. New uses for wool include mulches, needle-punch pads, and booms, socks, and mitts to soak up oil and other materials from spills and leaks (table 11).

Wool Goes Through Several Processing Steps

The first step in wool processing takes place on the ranch where the sheep are shorn or clipped. The wool is sorted by length and fineness for its intended use in either the worsted or woolen system. Worsted and woolen are the two major classifications for wool yarns and fabrics. The primary difference between the two systems is the quality of the wool fiber they require and, thus, the value of the wool. The worsted system uses wool fibers that are of fine diameter and more than 3 inches in length. The fibers are combed and drawn during processing to make the individual fibers lie parallel and to eliminate shorter fibers, called noils. Worsted yarn is used to produce higher quality wool products, such as suits, dresses, gabardines, and crepes. The woolen system uses shorter wool fibers to make fluffy yarns for sweaters, coats, and carpets. Beside raw wool (wools that have not been previously processed), the woolen system uses noils from the worsted system.

Table 11–Nonapparel uses for wool

Category	Uses
Pressed felts	Hats Banners Piano hammers Board erasers Insoles
Carpets	Rugs Tufted carpets Carpet underlay
Blankets and bedding materials	Home Emergency/hospital
Furnishings	Upholstery (fabric covering and filling in homes, cars, and airplanes Wall coverings Office dividers Soundproofing barriers Gaming table covers
Mattress filling	Filling component Futons
Quilt fillings	Comforters Mattresses Pillows Quilted jacket lining Cushions
Industrial and other uses	Oil or hazardous-material clean-up pads Structural insulation Baseball winding Ballet-shoe toe padding Padding (saddles, bicycle seats, sports equipment, etc.) Cleaning aids or tools Car insulation Fluid filters (oil, etc.) Glove padding Mulch pads (erosion control)

Source: National Lamb and Wool Grower, May 1996.

Properties of wool that affect its value include fineness, fiber length, strength, color, the number of intermingled black fibers, and the presence of vegetable and foreign matter mixed in it. Fleece wool, which comes from the main body of the sheep, is normally separated from the belly and the skirtings. Fleece wool is evaluated for its quality and usually sold to processors in the worsted system. Belly wool is of good fineness but is shorter, relatively weak, discolored, and likely to carry vegetable matter. Belly wool is best suited for the woolen system. Finally, the skirtings provide the coarsest wool, which is often stained and is likely to carry kempy hairs (stiff, unsnippable fibers that will not take a dye). Skirtings are best used by the woolen system or in nonwoven applications.

After the fleece is clipped from the sheep and sorted, the wool is scoured or washed to remove grease and foreign matter, which can account for 30 to 70 percent of raw (unscoured) fleece weight. Wool is then passed through a system of wire rollers that straighten the fibers and remove any remaining vegetable matter. This process, called carding, produces a waste material that can be blended back into the spinning process with other wool to produce special-effect yarns or it can be sold for use in other markets.

Wool is a natural protein fiber, similar to the protein found in human hair and fingernails. Properties of protein fibers, including low flammability, flexibility, and absorbency, make wool an excellent candidate for industrial applications. Wool is normally regarded as a safe flammable material since it burns very slowly and is self-extinguishing. Wool can also be given a flame-retardant finish with little effect on the physical or chemical properties of the fiber. Second, wool has excellent flexibility. The fibers can be bent back on themselves 20,000 times without breaking, as compared to 3,000 times for cotton and 75 times for rayon. Finally, wool can absorb moisture in vapor form

and repel moisture in liquid form (up to 30 percent of its weight) without the surface feeling wet.

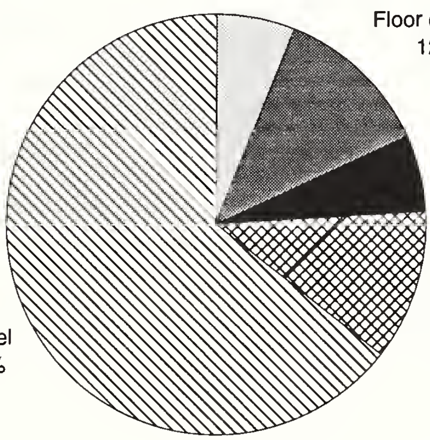
Most Wool Is Used for Apparel

The 1996 U.S. supply of raw wool is estimated at 175 million pounds, clean (after scouring), 10 percent below last year (table 12). Stocks at the beginning of 1996 are estimated to have been 40 million pounds. Estimated 1996 wool production, at 30 million pounds, is 11 percent less than the previous year. U.S. raw wool imports are 85 million pounds, 4 percent below 1995.

The apparel industry accounts for the largest share of raw wool, using more than 64 percent on average during 1990-94 (figure 5). Although most wool is used in the apparel industry, some of the lower quality wool is not suitable for this use and can be put into nontextile or industrial applications. Nearly 6 percent of raw wool was used in industrial and other consumer products during 1990-94. This category includes, for example, mattress felts, felts for filtration, and shoe padding.

In addition to low-value wool, wool waste from the worsted and woolen industries is also available for industrial uses. Each step of the manufacturing process (carding, combing, spinning, weaving, and fabric cutting) produces wool fiber wastes that can either be blended back into the wool processing system or used directly to form nonwovens. Ron Aljoe of National Nonwovens estimates there are 30 million pounds of low-value wool and wool waste available each year that are suitable for industrial uses.

Figure 5
U.S. Consumption of Wool by End Use, 1990-94



Source: Fiber Organon, September 1995.

Demand for New Wool Products Is Growing

Consumers' perception of the benefits of using natural products has stimulated interest in industrial uses of wool. Although many industrial wool products, such as felts for piano hammers, cleaning tools, and stuffing for gloves and saddles, have existed for years, markets for some higher value wool products are still being developed. The perceived lack of a constant supply for industrial applications can explain some manufacturers' hesitancy in using wool as a major input. They are concerned with finding a consistent and inexpensive source of lower grades of wool and wool wastes. To this end, manufacturers are looking for ways to retrieve the wool they need before it goes through all of the processes required for apparel use. Retrieving the wool before these processes would make it less expensive.

Despite the supply concerns, many firms are capitalizing on the unique properties of wool. For example, Hobbs Bonded Fibers of Waco, Texas, is selling Wool-Zorb products, a range of oil spill clean-up products made from wool. These wool products can absorb more oil than polypropylene, can float on top of the water, and are reusable because the oil can be squeezed out of the sorbent up to eight times. And unlike polypropylene, which is not biodegradable, wool can biodegrade under favorable, controlled conditions, eliminating the costs for hazardous waste storage. Wool absorbents can also be used in other industries where chemical spills and leaks occur, such as garages, refineries, and machine and printing shops. Hobbs Bonded Fibers processes 100,000 to 150,000 pounds of wool per year in its oil spill products and needle-punch pads for use as mattress tops and nonwoven blankets.

Another example of lower quality wool use is wool mulch. The Appleseed Wool Corporation of Plymouth, Ohio, sells a mulching and weed suppression wool mat. According to the company, "Ewemulch" is aesthetically more pleasing than black plastic and is easy to lay. It will allow water to pass through to the soil while acting as a barrier to reduce soil desiccation during dry periods and as an insulator un-

Table 12--U.S. wool supply and use, 1990-96

Year	Beginning stocks January 1	Production	Imports	Unaccounted	Total supply	Mill use	Exports	Total use	Ending stocks
	Million clean pounds								
1990	89.2	46.8	71.7	7.1	214.8	132.7	2.7	135.4	79.4
1991	79.4	46.7	86.5	7.1	219.7	151.5	3.9	155.4	64.3
1992	64.3	44.1	89.3	4.5	202.2	150.8	3.4	154.2	48.0
1993	48.0	41.2	100.3	7.0	196.5	156.8	2.5	159.3	37.2
1994	37.2	36.5	91.7	42.5	207.9	153.3	2.9	156.2	51.7
1995	51.7	33.6	88.8	20.0	194.1	148.2	6.0	154.2	39.9
1996 1/	39.9	30.0	85.0	20.0	174.9	140.0	3.0	143.0	31.9

1/ Forecast.
Sources: Bureau of Census and USDA.

der moist conditions. After 1 year, wool is degraded sufficiently to be incorporated into the soil and becomes a supplier of nutrients. Ewemulch mats are also available preseeded with wildflower or other plant seeds for a variety of applications, such as creating a butterfly or wildlife habitat. Appleseed also sells hanging basket liners and carpet pads made from wool. The company estimates its yearly use of wool to be 80,000 to 100,000 pounds, including imported wool waste.

Lanolin Supply Down, Prices Stable

Raw wool contains 10 to 25 percent grease, or lanolin, which is recovered during the scouring process. Lanolin consists of a highly complex mixture of esters, alcohols, and fatty acids and is used in adhesive tape, printing inks, motor oils, and auto lubrication. It can also be refined for use in cosmetics and pharmaceuticals. Virtually all cosmetics and beauty aids, such as lipsticks, mascara, lotions, shampoos, and hair conditioners, contain lanolin.

U.S. regulations require lanolin to be free of contaminants, such as pesticides, if it is used in cosmetics or pharmaceuticals. Cosmetic-grade lanolin cannot contain foreign contaminants exceeding 40 parts per million (ppm), and not more than 10 ppm of any one contaminant. Lanolin for medical applications has a total contaminant limit of 3 ppm. These regulations were originally opposed by the lanolin and cosmetics industries, but now are seen as a potential selling point for safety to consumers.

The supply of lanolin depends on the amount of wool scoured. And with wool processing down at the moment, supplies of woolgrease have fallen. Industry sources estimate the U.S. market for lanolin to be about 5 million pounds per year, with approximately 70 percent satisfied by domestic production. The demand for lanolin has been steady for several years because lanolin is considered by many analysts to be a mature industry, with limited growth prospects. Many suppliers are concerned that the public's perception of lanolin as an animal-derived product has adversely affected its potential for future market growth. [Jacqueline Salsgiver, ERS, (202) 501-7107, jsalsgiv@econ.ag.gov]

Supply of Recovered Wood and Paper Is an Impetus for Recycling

Approximately 37 million metric tons of paper and wood materials were recovered for recycling in 1994, providing a renewable source of inputs to manufacturers. Finding new markets for wastepaper and waste wood is essential to the growth of the recycling industry.

Wood and wood fiber, in the form of discarded paper, wood products, and yard wastes, account for more than half of the municipal solid waste (MSW) by weight in the United States. Mounting concern for long-term environmental, economic, and human health problems associated with landfills and waste incineration has spurred both an expansion in collecting and sorting of recyclables and gains in wood-product-recycling technology.

Besides recycling, wood and paper products can be incinerated both as a means of diverting waste from landfills and as a source of energy. In the United States, most of the incineration of wastepaper and waste wood occurs in MSW facilities. However, such combustion facilities have high operating costs, including expenses to maintain adequate control over air emissions and disposal of the ash residue, which may be regarded as hazardous waste. At the present time, the operating costs of incineration are greater than the revenues from the sale of the energy produced. Facilities make money by charging tipping fees for accepting garbage. As prices for recovered paper continue to increase, as projected by USDA's Forest Products Laboratory, without energy price and tipping fee increases, there will be a greater incentive to sort out wastepaper for sale in the recyclable paper market.

Composting is another alternative for wastepaper and waste-wood disposal. Compost is a relatively inert soil amendment or mulching material, but as an end product, it has little value. Therefore, composting is an economic option for wastepaper and waste wood only if these goods are considered to have little or negative value.

Finding higher value markets for recycled paper and wood is critical to the success of the wastepaper and waste-wood recycling industry. New markets will help raise the demand for recovered paper and wood, which will raise prices for recyclables. In turn, the price increases will provide an economic incentive for sorting and recycling while decreasing the amount of MSW deposited into landfills. Today, many recycled paper and wood products receive a low price because wastepaper and waste wood compete with other low-value materials, such as animal bedding straw and garden mulch, or because they are perceived to be inferior to competing inputs, such as foam or fiberglass for insulation or foam plastics used in lightweight containers. Continued research on products that can benefit from wastepaper and waste wood will help these materials enter higher value markets in the future.

Recycling Has Accelerated

By 1994, the latest year for which data are available, 37 million metric tons of paper and wood materials were recovered for recycling into new products, up from 20.4 million tons in 1986. Domestic paper and paperboard mills, the largest users of recovered fiber, increased their use by nearly 75 percent to 28 million tons in 1994. Use in miscellaneous or industrial products more than doubled between 1986 and 1994 to an estimated 1.5 million tons. Exports of recovered fiber accounted for 7 million tons in 1994, up 75 percent from 1986. Not only has the volume of recovered waste increased, the share of recovered wastepaper and wood also has risen since 1986. Approximately 40 percent of paper and paperboard was recovered for recycling in 1994, compared to only 28 percent in 1986.

In addition to the wastepaper and waste wood component of MSW diverted from landfills, other sources exist for recycled wood fiber. Demolition waste and new-construction waste are two other important sources of waste wood available to recyclers.

Wastepaper and Waste Wood Have Many Industrial Uses

Beside paper and paperboard products, other items made from recycled paper and wood include cellulose insulation, molded-pulp products, animal bedding, paper mulch, packaging cushioning material, and wallboard panels (table 13). According to the American Forest and Paper Association, industrial use of recovered paper (other than for paper and paperboard) is estimated to have more than doubled between 1986 and 1994, but the total quantity is still estimated to be only around 1.5 million metric tons per year.

Cellulose insulation is the second largest category of recycled paper and wood consumption, with 55 reported producers in this enterprise in 1995. The recycled materials, consisting mainly of old newspapers, are pulverized or fiberized and treated with fire retardants (inexpensive inorganic chemicals such as borax). The product is used as a loose fill for insulation of attics and walls, where it is usually poured or blown into place, or it can be mixed with water and adhesives for application as a wet spray. Other insulation products include insulation blocks, barriers, and insulation baffles. Cellulose insulation accounts for only 4 percent of the building insulation market, which is dominated by fiberglass and plastic foam panels.

Molded-pulp products, used mainly for packaging, account for the third largest consumption of recycled paper and wood

Table 13--Approximate quantities of wood and wood-fiber materials recovered for recycling in the United States, 1994

Use category	Approximate quantity
	Metric tons
Paper and paperboard	28,100,000
Recovered paper for export	7,000,000
Insulation and related products	500,000
Molded-pulp products	300,000
Fiberboard products	275,000
Wooden pallets	250,000
Animal bedding	100,000
Mulch	100,000
Particleboard, hardboard 1/	50,000
Reclaimed lumber 1/	50,000
Roof systems, siding 1/	50,000
"Plastic lumber" and other 1/	10,000

1/ Estimated, not based on actual survey data.

Source: USDA, Forest Service, Forest Products Laboratory.

products. By the early 1990's, there were 13 producers of molded-pulp products, which accounted for 300,000 metric tons of recycled paper. These products include protective packaging in shipping containers, food packaging, such as food service trays and egg cartons, and horticulture plant pots. Currently, molded-pulp products are overshadowed by polystyrene and other plastic foam packaging materials in the packaging market.

Waste paper can also be used as a feedstock in the manufacture of fiberboard products. For example, Gridcore Systems International Corporation in Long Beach, California, is manufacturing Gridcore panels, a strong, lightweight, molded-fiber panel developed and patented by USDA's Forest Products Laboratory. A Gridcore board consists of two subpanels of molded fiber, each with one smooth surface and one waffle-textured surface, bonded together on the waffled sides, so the smooth surfaces face outward. The panels are made primarily from waste corrugated cardboard, which provides the long fibers necessary to maintain structural integrity, and from recycled newsprint and office paper. Fibers from other sources, such as wood waste from construction and demolition debris, rice hulls, kenaf, jute, and bagasse, can also be used. The panels are produced by mixing waste cardboard or cellulosic fibers with water and pouring them into a compressible rubber mold. The water component is vacuumed out of the pulp, and the newly formed panel is transferred to a hot press (*1*). Gridcore panels are currently being marketed for theater and television stage sets, exhibit or trade-show displays, and office partitions. Future applications of Gridcore will capitalize on its light weight and strength, and include shipping containers and wall, floor, and roof panels.

Particleboard and hardboard is another market for recycled paper and wood products. The annual quantity of recycled wood used is estimated to be about 50,000 metric tons or 1 percent of the industry's total wood use. For instance, Evanite Fiber Corporation in Corvallis, Oregon, is recycling urban waste wood to make a hardboard product for use as paneling and pegboard. Evanite's hardboard is constructed of 48 percent urban wood waste; 45 percent scrap pallets, shakes, and utility spools; and 5 percent virgin wood. Currently, Evanite produces approximately 1.5 million cubic feet of hardboard per year, using nearly 37,000 metric tons of waste wood fibers (*1*).

Waste paper and wood can also be combined with concrete, plastics, or other materials to form composite products, which can combine the best properties of each input. For example, Insul Holz-Beton International, Inc. (IHBi) of Windsor, South Carolina, licenses the manufacture of wood-cement building products and insulating wall forms. IHBi developed a process to impregnate wood with a nontoxic mineral emulsion to preserve the wood cellulose and protect the chips against rot and decay. The wood aggregate is mixed with portland cement to form lighter weight, fireproof building materials and components. The organic fiber makes up 91 percent (by volume) of the total composition. Using the same process, IHBi also licenses, under the tradename Faswall, permanent insulating wall forms for reinforced concrete structures. The wall forms have a 4-hour fire rating and a R-value of 11 to 24, depending on configuration.

Recycled newspaper is combined with soybean flour to form a decorative surface product that looks like granite but handles like wood. Phenix Biocomposites, Inc., of St. Peter, Minnesota, currently produces Environ for use in furniture, store fixtures, and plaques. Products may be developed in the future for use in the structural building materials market.

Recycling Research Continues

Additional recycling technologies are under research and development. Emphasis is on finding markets for currently unusable recyclable fiber, such as magazines, food-packaging containers, and urban waste wood. One example of new research has shown that urban wood waste can be mixed with fiberglass waste from sheet molding to produce subflooring panels. The result is a stronger, less expensive panel, and new uses for two products that would otherwise fill valuable landfill space.

Improving the recycling value of juice boxes, milk cartons, and other food-packaging containers is another area of investigation in recycling research. Recyclers tend to like these low-cost, high-quality fiber containers but separating the fiber from the plastic film (low-density polyethylene) used to coat them creates wet film waste. Up to 50 percent of the paper fiber is lost in the waxy slurry during the separation process. The Forest Products Laboratory, in collaboration with university and private industry, has developed technology that thickens the film waste and creates pellets that can be used in typical plastic-molding equipment. [Jacqueline Salsgiver, ERS, (202) 501-7107, jsalsgiv@econ.ag.gov, and Peter Ince, Forest Service, Forest Products Laboratory, (608) 231-9364, pjince@facstaff.wisc.edu.]

1. Lorenz, David. *A New Industry Emerges: Making Construction Materials From Cellulosic Waste.* Institute for Local Self-Reliance, Minneapolis, MN, 1995.

Interest Increases in Using Plants For Environmental Remediation

In an effort to meet environmental regulations of the last three decades, environmental remediation has developed into a multibillion dollar industry. The high cost of many traditional methods is causing many organizations to look to lower cost alternatives. Bioremediation is a commercial remediation technology with a growing market and continuing research. Phytoremediation is another potential low-cost technology that is currently being investigated for many remediation applications.

Health and environmental risks of pollution have become more apparent throughout the world over the past several decades. Air, water, and soil contaminants can include numerous organic and inorganic substances, such as municipal waste and sewage, various gaseous emissions, fertilizers, pesticides, chemicals, heavy metals, and radionuclides (radioactive substances). Contaminants can cause land and groundwater to be unusable. In addition, animals and insects may come in contact with a contaminant, thus introducing a toxic substance into the food chain. Because of increased public awareness and concern, environmental regulations have been created to not only prevent pollution, but also to remediate areas where environmental contamination has occurred. As a result, environmental remediation is a rapidly developing multibillion dollar industry.

Remediation Technologies Are Evolving

Environmental remediation technologies use physical, chemical, or biological processes that attempt to eliminate, reduce, isolate, or stabilize a contaminant or contaminants. Depending on the technology used, the process may either take place at the location of the contamination (*in situ*), or the contaminated soil or water may be removed for *ex situ* treatment (table 14). Every remediation technology has certain limitations and disadvantages. Therefore, site-specific evaluations must be made to assure the appropriate technologies are applied. If multiple contaminants are involved, it may be necessary to use a combination of techniques to reduce the concentrations of pollutants to acceptable levels.

The economic costs of environmental remediation can be tremendous. Various studies have estimated that cleanup of current hazardous waste sites with conventional technologies would cost from $400 to $750 billion in the United States alone (*5*, *7*). Over the next 5 years, remediation of U.S. sites contaminated with heavy metals could cost over $7 billion, and sites contaminated with a mixture of heavy metals and organics could cost another $35 billion (*1*). Remediation of radionuclides from soil and water at identified U.S. Department of Energy (DOE) and Department of Defense (DOD) sites could cost over $10 billion using current treatment technologies (*5*).

The high cost of remediation is perhaps the driving factor in the development of new remediation technologies. For example, incineration and landfilling are two of the oldest and most widely used methods of soil remediation. They

Table 14--Soil remediation technologies

Method	*In situ*	*Ex situ*
Physical	Soil vapor extraction Thermally enhanced soil vapor extraction Containment systems and barriers	Landfilling Incineration Thermal desorption Soil vapor extraction
Chemical	Soil flushing Solidification Stabilization	Soil washing Solidification Stabilization Dehalogenation Solvent extraction Chemical reduction and oxidation
Biological	Bioremediation Phytoremediation	Land farming Bioreactors

Source: European Institute for Environmental Education and Training.

are both highly effective in eliminating contaminants from their current environment, but both are relatively expensive compared to other methods. In addition, incineration also raises the question of air pollution, and landfilling simply moves the contaminated soil from one location to another.

Bioremediation, the systematic use of microorganisms for environmental contaminant treatment, is a developing technology that is currently used (though on a relatively small scale) to clean some sites of halogenated and nonhalogenated volatile and semivolatile organic compounds and petroleum hydrocarbons. The contaminants are degraded by naturally occurring microbes that are stimulated by introducing nutrients, oxygen, and other amendments to the soil or water. Considerable research is being done on this technology, and the potential market for well-developed techniques is large. Burt Ensley, president of Phytotech, Inc., a Monmouth Junction, New Jersey, phytoremediation company, estimates that the current market for bioremediation in North America and Europe is around $500 million, and by the year 2000 could be $1 billion or more.

Phytoremediation Is a Potential Low-Cost Alternative

Another potential biobased low-cost alternative technology is phytoremediation—the systematic use of plants for environmental contaminant treatment. Phytoremediation is a

combination of technologies that use "plant-influenced biological, chemical, and physical processes that aid in the remediation of contaminated substrates" (*3*). For phytoremediation to be possible, contaminants must be within the plant's root zone, and must be biologically absorbed and/or processed (bioavailable).

The four main technologies of phytoremediation are: rhizofiltration, phytoextraction, phytostabilization, and phytodegradation. In rhizofiltration, plants (primarily their root systems) absorb contaminants, such as heavy metals and radionuclides, from water and, in some cases, translocate the contaminants to stems and leaves. Phytoextraction uses plants to absorb contaminants, such as heavy metals, from soil into roots and harvestable parts, such as stems and leaves. Phytostabilization uses plants that are tolerant of a contaminant in soil, such as heavy metals, to reduce the contaminant's mobility and prevent further environmental contamination, such as leaching into ground water or becoming airborne by wind erosion. Phytodegradation is plant-assisted bioremediation, in which degradation of contaminants, such as various organic compounds, occurs during a plant's metabolic process or is influenced by plant-root and soil microbial activity (rhizodegradation).

Constructed Wetlands Clean Wastewater

Commercial use of phytoremediation is currently very limited, as most technologies are still primarily experimental. Perhaps the most developed and widely used phytoremediation application is the use of constructed wetlands (artificial marshes) for wastewater treatment. Artificial marshes, a rhizofiltration technology, have been constructed to help treat wastewater from municipal sewage treatment facilities and several industrial processing operations.

Two such artificial marshes were constructed in Magnolia, Arkansas, to treat rainwater runoff and noncontact process water from Albemarle Corporation's bromine production facilities. Each marsh consists of thousands of plants like bulrush, maiden cane, and cattails. The first marsh, about 54 acres in size, was created at the South bromine facility and began operation in 1993. The second marsh, constructed at the West facility, is about one-fourth the size of the South facility, and began operation in October 1995. The marshes are less expensive to create, and have a considerably lower operating cost, than a mechanical wastewater treatment system. The marshes have been referred to as "the cheapest alternative for dealing with the increased demands of the Clean Water Act" (*4*).

Another constructed wetland is used by Chevron at its Richmond, California, crude oil refinery to reduce selenium waste from crude oil refining. In high doses, selenium can be toxic to fish and wildlife. The 90-acre wetland can take in 1 to 3 million gallons of wastewater per day. It takes approximately 7 days for the water to work its way through the system, which consists of primarily bulrush and cattails, resulting in a reduction in selenium. The wetland can periodically be dried and the vegetation harvested for proper disposal. Recent research sponsored by Chevron at the University of California-Berkeley indicates that a portion of the selenium removed by the wetland plants is volatilized in a less toxic form.

Sunflowers Remove Radionuclides From Water

Other rhizofiltration applications seem to be among the most promising phytoremediation technologies. Because of the Clean Water Act, water quality has become a major concern of regulatory agencies and industrial producers. As a result, research and development opportunities for potential low-cost water remediation methods, such as rhizofiltration, have developed.

Successful rhizofiltration techniques require identification of species of plants that have the ability to process large quantities of water and sequester certain contaminants in plant biomass. An example of such a plant is a special strain of sunflower that, when grown hydroponically on rafts, has removed radionuclides from water. The system was developed and patented by Phytotech, Inc. According to the company, the sunflower rhizofiltration system can successfully reduce uranium, strontium, and cesium levels in water to below cleanup standards set by the U.S. Environmental Protection Agency (EPA). Accumulation of uranium occurs primarily in the roots, whereas strontium and cesium accumulate throughout the plant.

The system has worked effectively at test sites near the Chernobyl nuclear plant in Ukraine, as well as at a DOE site in Ohio. Phytotech estimates the cost to remove radionuclides from water would be between $2 and $6 per 1,000 gallons, including disposal costs. A standard treatment of microfiltration and precipitation would cost nearly $80 per 1,000 gallons, according to DOE estimates. If approved by EPA regulators and site owners, the process could be commercialized within 1 year.

Poplar Trees Protect Groundwater And Streams

Trees have many potential phytoremediation applications simply due to their structure and physiology. They typically have extensive root systems, with the ability to penetrate the soil several feet down, sometimes to groundwater tables. Extensive root systems often support growth and diversity of soil microorganisms, which aid in degrading contaminants. Many species of trees also offer other advantages, such as transpiration of large quantities of water (absorbing water from soil and emitting it as water vapor through foliage), large plant biomass, long life spans, ability to grow on low-fertility soil, and the promotion of ecosystem diversity (*7*).

Some species of trees are currently being used to remediate organic pollutants. Hybrid poplar trees, for example, are used as buffers and caps to prevent pollutants—for instance, from landfills—from reaching waterways and groundwater. The poplar-tree systems were developed at the University of Iowa and are now being used commercially by Ecolotree, Inc., of Iowa City, Iowa, a private spinoff company. Since 1990, Ecolotree has installed caps and buffers at 30 permitted sites in 11 States and Europe.

Seven landfills in Virginia, Iowa, and Oregon are using poplar trees to manage water. An example of a full-scale Ecolotree Cap is at Lakeside Landfill in Beaverton, Oregon. In its seventh year of operation, the cap has been suc-

cessful in keeping the landfill free of leachate problems. Another full-scale site at Riverbend Landfill in McMinnville, Oregon, uses an Ecolotree Buffer of 14.3 acres of hybrid poplars to transpire landfill leachate, which is irrigated onto the poplar stand. According to the company, this is an effective, low-cost alternative to pumping the leachate to a wastewater treatment facility.

Ecolotree has also planted the hybrid poplars as buffer systems to filter water and air, while stopping erosion and degrading pollutants in the soil. For example, in Amana, Iowa, poplars were planted in four rows along a stream in an effort to intercept nitrate pollutants from nearby farmland before they reached the stream and groundwater. According to Ecolotree president, Louis Licht, in the second year of establishment, the tree-lined stream contained 50 percent less nitrate nitrogen and 85 percent less sediment compared to an adjacent unbuffered watershed. Nitrate nitrogen in groundwater flowing through the buffer was also decreased significantly. Ecolotree Buffer systems have also been used at agrochemical dealerships owned by Clarence Cooperative of Clarence, Iowa. The hybrid poplars have been used to remove chemicals at urea fertilizer spills, old herbicide-equipment rinsing areas, and perimeter buffers as a final filter for surface and ground water.

Poplar tree research is continuing at the University of Iowa, focusing on the fate and movement of solvents, ammunition (such as TNT), herbicides, fuels, and organic intermediaries for various plastics. Other organizations involved in poplar research include the EPA Laboratory in Athens, Georgia, the National Salinity Laboratory in Riverside, California, the Bioresource Engineering Department at Oregon State University, and Phytokinetics of North Logan, Utah. Phytokinetics has commercial applications using poplar technologies, which have been used in several States to remediate groundwater.

Phytoremediation of Inorganics in Soil

In addition to the development and commercial applications of rhizofiltration, research and development are underway on using phytoextraction and phytostabilization to sequester inorganic elements and compounds. (Some organic compounds may also be destroyed by these technologies.) Potential remediation sites and their inorganic contaminants include abandoned mines and smelting operations (heavy metals), military sites (heavy metals and radionuclides), and nuclear energy and waste sites (heavy metals and radionuclides).

Because of the high cost of current heavy-metal remediation methods, much of the soil phytoremediation research has focused on their removal. Scott Cunningham, a scientist at Dupont Central Research and Development in Newark, Delaware, suggests that potential phytoremediation techniques could cost significantly less than current heavy metal remediation methods. In a recent presentation at a phytoremediation conference in Arlington, Virginia, Cunningham compared potential costs. He said that remediation of 10 acres contaminated with lead using current technologies could cost as much as $12 million. This includes planning and documenting the project, as well as the actual decontamination process. In comparison, potential phytoremediation methods for the same area could cost as little as $500,000. In addition, many phytoremediation costs can be spread out over the life of the project (which may be years), whereas traditional remediation technologies typically call for large up-front expenditures. This lower cost potential of phytoremediation is driving organizations like Dupont, Phytotech, Argonne National Laboratory, DOE's Office of Science and Technology, and USDA's Agricultural Research Service (ARS) to research the removal or stabilization of heavy metals by plants. Much of the research is centered on hyperaccumulators, plants that absorb levels of metal that would be toxic to most other plants.

Though many hyperaccumulator plants are relatively small in size (low biomass) and take a long time to grow, several species are showing some promise as heavy metal phytoextractors. One such plant is Alpine pennycress (*Thalaspi caerulescens*), which hyperaccumulates zinc and smaller amounts of cadmium. Field trials are currently being conducted by ARS at a Superfund cleanup site in Palmerton, Pennsylvania, to test ways to remove zinc and cadmium. The site is managed by the Zinc Corporation of America, and is thought to have been contaminated by a zinc smelter that operated in Palmerton from 1890 to 1980. The low harvestable biomass of pennycress is a restricting factor that scientists from USDA, the University of Maryland, and the University of Sheffield in the United Kingdom are trying to overcome. *Thalaspi* strains are being collected and crossbred in an attempt to maximize cadmium and zinc concentration in the plant, as well as create plants that grow faster and taller. This work will also likely lead to genetic screening in an attempt to isolate genes responsible for metal uptake, so they can potentially be transferred to other higher yielding biomass plants.

Another potential technology for heavy metal remediation is phytostabilization, also referred to as IINERT (in-place inactivation and environmental restoration). This technology is currently being investigated by Dupont and others for use at sites where extraction is logistically difficult. The objective is to use soil amendments to reduce the bioavailability of the metals in the soil matrix. Certain plants are then grown to trap the remaining contaminants in the roots. This further reduces the bioavailability of the metals to other plants and animals and helps prevent leaching and off-site migration of the metals (*2*). Contaminants are likely to be phytostabilized more quickly than they can be phytoextracted. However, phytostabilization is not yet accepted by EPA, as research is still needed to determine overall effectiveness and long-term stability achieved by this technology.

Indian Mustard Plant Extracts Heavy Metals And Radionuclides from Soil

Some current research and development is also being done on plants that can remediate both heavy metals and radionuclides. For example, Indian mustard (*Brassica juncea*), a high-biomass crop that traditionally has been grown in Southeast Asia as a source of cooking oil, has recently shown some promise in uptake of some heavy metals, radionuclides, and other inorganic chemicals. ARS's Water Management Research Laboratory in Fresno, Califor-

nia, has had success in using Indian mustard to dramatically reduce selenium levels in soil. In some areas of California where irrigation is vital to agriculture, evaporation ponds for drainage water may leave a high selenium residue behind. Making Indian mustard part of a proper crop rotation can help control selenium levels and minimize the selenium load deposited into the agricultural effluent. In addition, some of the harvested mustard can be blended with hay and fed to animals in nearby areas where selenium deficiency is a problem. In order to see if *Brassica* species used for selenium uptake could be used as viable oil crops, scientists currently are evaluating the effects of higher selenium concentrations on oil content.

Based on Indian mustard germplasm collected by ARS, studies conducted by Phytotech, Rutgers University, and the International Institute of Cell Biology have also shown that Indian mustard has the ability to accumulate heavy metals such as lead, chromium, cadmium, nickel, and zinc. The approach requires adding a chelating agent to the soil to solubilize the soil lead, and allow it to move from the roots into the shoots. Field trials are being conducted this year in Trenton, New Jersey. However, it is not clear whether future environmental regulation will allow adding such high levels of chelating agents to the soil, as increased mobilization of contaminants may pose a threat to ground water. Phytotech has also had some success in using Indian mustard to remove radionuclides such as cesium-137 and strontium-90 at a site near Chernobyl.

Phytoremediation of Organics in Soil

Although heavy metals and radionuclides are a problem at many hazardous waste sites, a large number of sites are contaminated primarily with organic substances such as petrochemicals, chlorinated solvents, aromatic hydrocarbons, various pesticides and insecticides, explosives, wood preservatives, and surfactants. In many cases, phytoremediation of these contaminants in soil is a potential alternative to traditional cleanup methods. However, a major determining factor is the age of the contamination. Organic contaminants that have been in the soil for a long time tend to be less available for plant uptake, making phytoremediation improbable if not impossible.

Various types of phytoremediation can be used for soil-based organic contaminants. Phytoextraction could be used to target moderately hydrophobic organics, such as chlorinated solvents (*6*). The contaminants may then be stored in plant biomass or, in some cases, volatilized. One form of phytodegradation involves uptake of organic contaminants and degradation through metabolic processes within the plant. Another form of phytodegradation is rhizodegradation, in which organic contaminants in soil (such as TNT, chlorinated solvents, and petroleum hydrocarbons) are degraded by plant-root and/or soil microbes within the plant's root zone. Some organic contaminants may be degraded because of enzymes, sugars, alcohols, and acids released by plant roots. Other organic contaminants may be affected by soil microbes that are stimulated by various root exudates and/or the oxygen and organic carbon supplied by root systems.

As with most phytoremediation techniques, extensive research is being conducted by numerous public and private organizations to evaluate the effectiveness of various plants in removing or reducing organic pollutants. Phytokinetics is one company that has a number of laboratory and field trials in progress. Phytokinetics is working with Chevron Research and Technology Company to remove petroleum hydrocarbons from soil and groundwater, as well as to investigate the fate of volatile organic compounds in soils planted with vegetation. Phytokinetics also is working with Exxon Research and Engineering Company on the removal of petroleum hydrocarbons from soil. Recently, Phytokinetics was accepted into EPA's Superfund Innovative Technology Evaluation Program, which was created to encourage development and commercialization of new technologies for environmental cleanup. The 2-year project will evaluate the efficacy of phytoremediation of soil at a Portland, Oregon, Superfund site contaminated with wood preservatives.

As with heavy metal and radionuclide phytoremediation research, various Federal departments and agencies are working with universities and private organizations on organic-contaminated soil remediation research. One such project is being conducted by Kansas State University scientists in cooperation with the U.S. Navy at the Navy's Craney Island Fuel Terminal (CIFT) Biological Treatment Facility. CIFT, located in Portsmouth, Virginia, is the Navy's largest fuel facility in the United States. Small field trials are being conducted evaluating the abilities of bermuda grass, rye grass, tall fescue, and white clover to remediate soil contaminated with petroleum compounds. The project will also evaluate the plants' abilities to control leaching of contaminants. The field trials should be completed by May 1997.

The Future of Phytoremediation

Though phytoremediation technologies are still primarily in research and development phases, various applications have shown potential for success. This has helped to increase interest and research in both public and private sectors, in an attempt to develop phytoremediation into a commercially viable industry. Some key technical hurdles that must be overcome for an industry to develop and grow are:

- identifying more species that have remediative abilities,
- optimizing phytoremediation processes, such as appropriate plant selection and agronomic practices,
- understanding more about how plants uptake, translocate, and metabolize contaminants,
- identifying genes responsible for uptake and/or degradation for transfer to appropriate high-biomass plants,
- decreasing the length of time needed for phytoremediation to work,
- devising appropriate methods for contaminated biomass disposal, particularly for heavy metals and radionuclides that do not degrade to harmless substances, and

- protecting wildlife from feeding on plants used for remediation.

In addition to technical barriers, government regulations will also determine the overall success of phytoremediation. Because the remediation industry is compliance driven, phytoremediation technologies must demonstrate their effectiveness at meeting State and Federal regulations. This simply might not be possible in all situations with many current phytoremediation technologies, due to the nature of the contamination (for example, the age of contamination and relative bioavailability of the contaminants). For these technologies, changes in regulatory status and/or continuing technical improvements will be necessary for commercialization.

Because of all the factors needed for success, the likely size and growth rate of a phytoremediation industry are difficult to predict. Because contaminated soils tend to present more bioavailability problems, Scott Cunningham of Dupont believes most initial phytoremediation successes will come in treatment of contaminated surface and ground waters. Industry sources suggest potential sites for soil phytoremediation are areas with low to moderate amounts of contaminants near the surface. Because it may take a relatively long time for phytoremediation to work, the first target contaminants will also likely have to pose no immediate threat to health or risk of further environmental damage.

How soon phytoremediation will succeed as an industry is also uncertain. It offers many potential advantages over traditional remediation technologies, particularly its public acceptance and considerably lower cost. If these factors continue to drive government and private research and development, phytoremediation technologies could continue to evolve. If so, some industry experts believe commercialization of certain technologies could occur within the next 5 years. [Charles Plummer, ERS, (202) 219-0717, cplummer@econ.ag.gov]

1. Brown, Kathryn Sergeant. "The Green Clean: The Emerging Field of Phytoremediation Takes Root." *BioScience*. American Institute of Biological Sciences, Washington, DC, Vol. 45, No. 9, October, 1995, p. 579.

2. Cunningham, Scott. "Phytoremediation of Pb Contaminated Soils and Sludges." *Phytoremediation Conference Proceedings*. International Business Communications and U.S. Department of Energy, Washington, DC, May 1996.

3. Cunningham, Scott D. and William R. Berti. "Remediation of Contaminated Soils With Green Plants: An Overview." *In Vitro Cellular and Developmental Biology—Journal of the Tissue Culture Association*. Tissue Culture Association, Columbia, MD, Vol. 29P, October, 1993, p. 207.

4. Kirschner, Elisabeth, M. "Botanical Plants Prove Useful In Cleaning Up Industrial Sites." *Chemical and Engineering News*. American Chemical Society, Washington, DC, Vol. 73, No. 50, December 11, 1995, p. 22.

5. Salt, David E., Michael Blaylock, Nanda P.B.A. Kumar, Viatcheslav Dushenkov, Burt Ensley, Ilan Chet, and Ilya Raskin. "Phytoremediation: A Novel Strategy for the Removal of Toxic Metals from the Environment Using Plants." *Bio/Technology*. Nature Publishing Company, Vol.13, No. 5, May 1995, p. 468-469.

6. Schnoor, Jerald L., Louis A. Licht, Steven C. McCutcheon, N. Lee Wolfe, and Laura H. Carreira. "Phytoremediation of Organic and Nutrient Contaminants." *Environmental and Science Technology*. American Chemical Society, Washington, DC, Vol. 29, No. 7, July 1995.

7. Stomp, A.M., K.H. Han, S. Wilbert, and M.P. Gordon. "Genetic Improvement of Tree Species for Remediation of Hazardous Wastes." *In Vitro Cellular and Developmental Biology—Journal of the Tissue Culture Association*. Tissue Culture Association, Columbia, MD, Vol. 29P, October, 1993, p. 227.

Potential Niche Fuel Markets for Biodiesel And Their Effects on Agriculture

by

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Abstract: This analysis estimates possible biodiesel demand in three niche fuel markets the biodiesel industry has identified as likely candidates for commercialization: Federal fleets, mining, and marine/estuary areas. If a 20-percent biodiesel blend becomes a competitive alternative fuel in the coming years, these markets could demand as much as 100 million gallons of biodiesel. The Food and Agricultural Policy Simulator, an econometric-based simulation model of U.S. agriculture, was used to estimate the impacts of 20, 50, and 100 million gallons of soybean-oil-based biodiesel production on the agricultural sector. The results indicate the effect of increased soybean oil demand on the soybean complex (beans, oil, and meal) and net farm income would be small.

Keywords: Biodiesel, alternative fuels, renewable energy, soybean oil, agricultural commodities.

Biodiesel, a fuel derived from vegetable oils, animal fats, and waste cooking oils, may be one of the alternative fuels, along with ethanol, compressed natural gas, and methanol, to help government and industry meet requirements of the Clean Air Act Amendments of 1990 (CAAA) and the Energy Policy Act of 1992 (EPACT) (see past issues of this report for more information). While some studies have looked at the economic feasibility of biodiesel production, little has been done to examine the effects of an expansion of demand for vegetable oil on the agricultural sector. One exception is a study by the University of Missouri (*2*). However, this study only examines the effects of a hypothetical increase in the demand for soybean oil without attempting to estimate the potential expansion in demand caused by the creation of niche markets. This analysis, therefore, examines potential niche fuel markets for biodiesel if a 20-percent biodiesel blend becomes a competitive alternative fuel, and estimates how the increase in soybean oil demand will affect U.S. vegetable oil prices, commodity markets, and farm income.

Conceptual Framework

This analysis estimates possible biodiesel demand in three niche fuel markets the biodiesel industry has identified as likely candidates for commercialization: Federal fleets, mining, and marine/estuary areas (*5*). Data were gathered on diesel fuel use in each niche market. If biodiesel is used commercially, it may be as a 20-percent blend with 80-percent regular diesel fuel. Therefore, the potential for biodiesel in each of these markets is 20 percent of diesel fuel use.

Although biodiesel can be made from various vegetable oils, tallow, and waste cooking oil, to simplify the analysis, it is assumed that soybean oil is the sole feedstock. The amount of soybean oil required to produce biodiesel was calculated for each of the markets. Both biodiesel and soybean oil use were summed to estimate total potential demand. The Food and Agricultural Policy Simulator (FAPSIM), an econometric-based simulation model of U.S. agriculture, was then used to simulate the economic adjustments that might occur if 20, 50 and 100 percent of this demand materialized. FAPSIM's advantage is its ability to simulate exogenous changes. Hence, the model can track the impact of the possible production of soybean oil-derived biodiesel over a broad range of agricultural commodities.

Three Potential Niche Fuel Markets

Although biodiesel is widely used in Europe because of environmental concerns and tax breaks, it has yet to make a significant market appearance in the United States. At present, neat (100 percent) biodiesel is defined as an alternative fuel under EPACT Section 490.2 (*7*). However, for biodiesel to be competitive as an alternative fuel given current production costs, it will need to be blended with diesel fuel. The current pump price for petroleum diesel is $1.28 per gallon, including average Federal and State taxes. While there is no current commercial price for biodiesel and biodiesel blends, the median hypothetical market price for biodiesel is $4.25 per gallon, according to anecdotal information received by USDA's Office of Energy and New Uses (OENU). An estimated wholesale price for a 20-percent biodiesel blend is $1.99 per gallon (56 cents per gallon for the 80-percent diesel, 85 cents for the 20-percent biodiesel, 44 cents for Federal and State taxes, and 14 cents mark up). The biodiesel industry has targeted niche fuel markets, such as Federal fleets, mining, and marine environments, where biodiesel use could help mitigate environmental and health-related externalities and/or purchasers may be willing to pay its higher price as their first targets for commercialization.

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Federal Fleets. The potential of Federal fleets as a niche market is driven by Federal policies implemented in EPACT and CAAA. The U.S. Department of Energy (DOE) recognizes that Federal fleets' relatively large market share within on-highway use and their high vehicle turnover rate create a potential niche market for alternative fuels (*1*). One advantage of Federal fleets for alternative fuel suppliers is logistics; the demand could be met with a relatively few number of outlets as Federal fleets are centrally fueled at motor pools. Regular commuters, on the other hand, would have to search for refueling stations that may not be within a reasonable vicinity. Another benefit of having Federal fleets as a niche market is the uniformity of regulations, whereas other fleets may be subject to various State and local laws.

The Federal fleet diesel market amounted to an estimated 288 million gallons in 1991 (table A-1). Data were calculated based on the energy content of diesel fuel and average truck and bus fuel-consumption weights (*1*). This estimate is conservative because (*1*) the sample is limited to trucks and buses from civilian agencies, the Postal Service, and the military, and (2) on-highway transportation is a small fraction of total government demand. A 20-percent biodiesel blend equates to a niche market of 58 million gallons of biodiesel, with a soybean oil equivalent of roughly 443 million pounds.

Mining. The potential benefits of using biodiesel in underground and surface mining originate from the possible health and environmental externalities that biodiesel could address directly through its use as a fuel and indirectly as a dust suppressant. The U.S. Department of Labor's Mine Safety and Health Administration is working with the National Institute for Occupational Safety and Health and the U.S. Environmental Protection Agency to draft new regulations and guidelines on the possible detrimental health effects of diesel exhaust and silica (*3*, *8*).

Even though the impacts of diesel exhaust are not fully known, one possible benefit includes biodiesel's potential ability to mitigate some carbon monoxide, particulate matter, soot, and volatile organic compounds in underground mining. A study is underway comparing the costs and benefits using biodiesel blends versus exhaust aftertreatment technologies, such as water scrubbers, dry particulate filters, and ceramic filters (*10*). This information will help determine how cost competitive biodiesel can be in the underground mining market. Another possible benefit entails spraying mineral dust with neat biodiesel instead of petroleum diesel so it will stay on the ground. Dust suppression is needed to help prevent silicosis, a lung disease known as Black lung, which stems from breathing crystalline silica. Thus, because of its biodegradability, biodiesel would not contribute to water pollution in surface and underground mines.

Table A-1--Diesel use by Federal fleet trucks and buses in fiscal 1991, and potential biodiesel and soybean oil use

Vehicle type	Diesel use 1/	Potential biodiesel use 2/	Soybean oil equivalent 3/
	Million gallons		Million pounds
Buses	0.6	0.1	0.9
Trucks	287.0	57.4	442.0
Total	287.6	57.5	442.9

1/ Derived from total fuel use (estimated by on-highway energy content) based on the share of diesel fuel use for trucks and buses. Sources: (1, 4). 2/ As a 20-percent blend with diesel fuel. 3/ A gallon of biodiesel equals roughly 7.7 pounds of soybean oil.

In 1992, the mining industry (SIC codes 1011 to 1499) used 186 million gallons of diesel fuel (*6*). With a 20-percent blend, this niche market amounts to almost 37 million gallons of biodiesel and 285 million pounds of soybean oil (table A-2).

Marine/Estuary Areas. The idea of marine environments as a potential niche market focuses on the use of biodiesel as a method to mitigate the dangers of diesel fuel leaks and spills on lakes, rivers, and estuaries. A study conducted by the University of Idaho for USDA's Cooperative State Research, Education, and Extension Service, demonstrated that when compared to petroleum diesel, biodiesel and biodiesel blends are more biodegradable in an aquatic environment and, therefore, less of a danger to water quality and ecological degradation (*11*).

According to a biodiesel industry analyst, the commercial barge and shipping industries are unlikely to adopt biodiesel voluntarily due to the competitive nature of those industries, absence of regulatory pressure to move away from petroleum-based diesel fuel, and the fact that fuel presents a significant portion of overall operating costs (*10*). Biodiesel could, however, find a market as a fuel for large recreational boats. Boat owners are more likely to purchase biodiesel blends because they generally have higher discretionary incomes, are more likely to be concerned about the condition of their local marine environment, and

Table A-2--Diesel use by U.S. mining industries in 1992, and potential biodiesel and soybean oil use

Industry	Diesel use 1/	Potential biodiesel use 2/	Soybean oil equivalent 3/
	Million gallons		Million pounds
Bituminous coal and lignite minerals	117	23	180
Bituminous coal underground minerals	3	1	5
Crude and petroleum natural gas	14	3	22
Drilling oil and gas wells	14	3	22
Oil and gas field services	2	4/	3
Lead and zinc ores	10	2	15
Gold ores	10	2	15
Iron ores and miscellaneous nonmetallic minerals	4	1	6
Crushed and broken limestone and granite	9	2	14
Construction gravel	3	1	5
Total	186	37	285

1/ Source: (6). 2/ As a 20-percent blend with diesel fuel. 3/ A gallon of biodiesel equals roughly 7.7 pounds of soybean oil. Numbers do not add due to rounding. 4/ Less than 1 million gallons.

Table A-3--Recreational boat fuel use in 1991, and potential biodiesel and soybean oil use

	Fuel use 1/	Potential biodiesel use 2/	Soybean oil equivalent 3/
	Million gallons		Million pounds
Gasoline	893	--	--
Diesel	47	9	69
Other fuels	15	--	--
Total	955	9	69

-- = Not applicable. 1/ Source: (9). 2/ As a 20-percent blend with biodiesel. 3/ A gallon of biodiesel equals roughly 7.7 pounds of soybean oil.

fuel purchases are a small portion of annual boating expenditures. Based on a national diesel-fuel-consumption survey in 1991 of large privately owned recreational vessels done by Price Waterhouse for the U.S. Fish and Wildlife Service and the U.S. Coast Guard (*9*), the marine niche market for biodiesel is estimated at roughly 9 million gallons, an equivalent of 69 million pounds of soybean oil (table A-3).

While biodiesel may help lessen the impact of diesel fuel on marine environments, it is uncertain what the net pollution effects of increased biodiesel production would be. For instance, it is unknown how much the rise in soybean production would add to soil erosion, sedimentation, and fertilizer and pesticide runoff, and water pollution. This issue is currently being addressed by a joint project conducted by USDA and DOE through a life-cycle analysis of biodiesel (see the fats and oils section for information).

Total Demand. Table A-4 summarizes the potential demand for biodiesel and the corresponding increase in the demand for soybean oil in the United States from the three possible niche markets. Federal fleets constitute roughly 55 percent of potential biodiesel demand, followed by mining, 36 percent, and marine environments, 9 percent.

Three demand scenarios of 20, 50, and 100 million gallons of biodiesel are used in this analysis to gauge the impacts of low, medium, and high market penetration. Approximately 50 million gallons of biodiesel could be produced with current industrial capacity, according to OENU. Additional capacity would have to be pulled from soap and detergent manufacturing or would need to be built.

FAPSIM Model Results

The low-, medium-, and high-demand scenarios were simulated with FAPSIM by shifting the U.S. domestic demand for soybean oil by 154, 393, and 770 million pounds. It is assumed that the demand curve shifted by a constant amount each year during 1996-2000 in each of the simulations.

If soybean-oil-derived biodiesel was commercially used in the estimated amounts, the largest direct impacts would occur in the soybean oil market (table A-5). Depending on the scenario, increased demand would cause soybean oil prices to rise by 2.8 to 14.1 percent on average during the 5-year period. This corresponds to an increase of 0.6 to 3.1 cents per pound. Higher oil prices would reduce the demand from other sources of domestic use. For example, under the high-demand scenario, even though demand initially shifts upward by 770 million pounds, domestic demand would only increase by 526 million pounds each year. Higher oil prices also may lead biodiesel producers to seek cheaper feedstocks.

Higher soybean oil prices would have indirect impacts on other parts of the soybean complex. For instance, higher oil prices would increase the profitability of processing raw soybeans into oil and meal, which would lead to an expansion in the demand for raw soybeans by processors. Because of the greater demand, the price received by farmers for soybeans would increase 0.4, 1.0, and 2.0 percent, respectively, under the low-, medium-, and high-demand sce-

Table A-4--Possible increase in soybean oil demand from the three potential biodiesel niche markets

Item	Market penetration		
	Low	Medium	High 1/
	Million gallons		
Potential demand			
Federal fleets	11	27	54
Mining	7	19	37
Marine	2	5	9
Total	20	50	100
	Million pounds		
Soybean oil use			
Federal fleets	85	208	416
Mining	54	146	285
Marine	15	39	69
Total	154	393	770

1/ Potential biodiesel use in the niche markets sums to 104 million gallons, which was rounded to 100 million gallons by dropping fleet use from 57.5 million gallons to 54 million gallons.

Table A-5--Average annual impacts from an expansion in biodiesel use, 1996-2000

Item	Niche market scenario		
	Low	Medium	High
	Percent change from baseline		
Soybean oil			
Production	0.3	0.8	1.6
Domestic use	0.8	2.0	3.9
Decatur price	2.8	7.2	14.1
Soybean meal			
Production	0.3	0.8	1.6
Domestic use	0.2	0.6	1.1
Decatur price	-0.7	-1.7	-3.3
Soybeans			
Production	0.1	0.2	0.4
Crush	0.3	0.8	1.6
Farm price	0.4	1.0	2.0
Corn			
Production	0.0	-0.1	-0.2
Feed use	-0.1	-0.2	-0.3
Farm price	0.0	-0.1	-0.1
Livestock prices			
Broilers, farm price	-0.3	-0.7	-1.4
Hogs, farm price	-0.1	-0.4	-0.7
Choice steers, Omaha	-0.1	-0.2	-0.3
Net farm income	0.1	0.2	0.3

narios. However, as more soybeans are crushed, oil and meal production would increase, which would lead to an average decline in meal prices from 0.7 to 3.3 percent over the 5-year period.

Higher soybean oil demand would affect the corn and feed markets only slightly. Higher soybean prices would lead to a very small drop in corn production under the medium- and high-demand scenarios, as farmers shifted from corn to soybean production. The feed demand for corn would decline a bit more because lower soybean meal prices would cause livestock producers to feed more soybean meal and less corn.

The decline in meal prices would increase the profitability of livestock producers, which would lead to expanded livestock production. Larger retail supplies of meat and poultry products would drive down farm-level and consumer prices. The impacts on the poultry market would be particularly pronounced, since soybean meal constitutes a larger portion of the feed ration for poultry relative to other livestock.

Under all three scenarios, higher soybean prices would lead to higher cash receipts for crops, while lower farm prices for livestock would result in lower cash receipts for these products. Since these two components of cash receipts move in opposite directions, the effects on total cash receipts would be mixed over the simulation period, increasing in some years and decreasing in others. Lower soybean meal prices, however, would reduce livestock production expenses enough to lead to a slight average increase in net farm income.

Conclusions

This analysis estimates possible biodiesel demand in three niche fuel markets the biodiesel industry has identified as candidates for commercialization: Federal fleets, mining, and marine/estuary areas. If a soybean-oil-based, 20-percent biodiesel blend becomes a competitive alternative fuel in the coming years, these markets could account for an additional 770 million pounds of soybean oil use. Based on FAPSIM simulations, the impact on U.S. agriculture would be small.

This is not a full cost-benefit analysis of shifting to biodiesel. It merely quantifies the possible impact on the U.S. agricultural sector if niche fuel markets for biodiesel should develop and soybean oil was the sole feedstock. However, if biodiesel commercialization occurs, cheaper raw materials, such as waste cooking oil and tallow, may be the primary feedstocks. Further scientific and economic studies are also needed to determine biodiesel's health and environmental costs and benefits.

References

1. Davis, S. *Transportation Energy Data Book: Edition 14*, ORNL-6798. Oak Ridge National Laboratory, Oak Ridge, TN, May 1994, 309 pp.

2. Food and Agricultural Policy Research Institute. "Increased Soybean Oil Demand: Its Effects on the Soybean and Corn Industries," CNFAP 16-94. University of Missouri, Columbia, MO, April 1994.

3. Hricko, A. "Considerations in the Use of Epidemiologic Data for Quantitative Cancer Risk Assessments." Speech for the Workshop on Diesel Exhaust, January 29, 1996, San Francisco, CA.

4. Miao, S.P., P. Hu, and J. Young. Fleet Vehicles in the United States: Composition, *Operating Characteristics, and Fueling Practices*, ORNL-6717. Oak Ridge National Laboratory, Oak Ridge, TN, May 1992, 58 pp.

5. National Biodiesel Board. *1996-98 Biodiesel Marketing Plan*. Jefferson City, MO, March 1996.

6. U.S. Department of Commerce, Bureau of the Census. *1992 Census of Mineral Industries*, MIC92-1-10A(P). Washington, DC, July 1994, 106 pp.

7. U.S. Department of Energy. "Alternative Fuel Transportation Program." *Federal Register*, Vol. 61 No. 51, March 14, 1996, pp. 10,629-30.

8. U.S. Department of Labor, Mine Safety and Health Administration. "Labor Secretary Aims to End Black Lung," News Release 95-007. Washington, DC, January 31, 1996.

9. U.S. Fish and Wildlife Service. *National Recreational Boating Survey: Final Report, Volume 1 of 2*. Report prepared by Price Waterhouse for the U.S. Fish and Wildlife Service and the U.S. Coast Guard, Washington, DC, June 1992, 67 pp.

10. Weber, Alan. October 1995. Personal communication.

11. Zhang, X., C.L. Peterson, D. Reece, G. Moller, and R. Haws. "Biodegradability of Biodiesel in the Aquatic Environment," ASAE Paper 95-6742. American Society of Agricultural Engineers, St. Joseph, MI, 1995.

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Table 15--Flaxseed: Acreage planted, harvested, yield, production, and value, United States, 1987-96

Year	Planted	Harvested	Yield	Production	Value
	---1,000 acres---		Bushels per acre	1,000 bushels	$1,000
1987	470	463	16.1	7,444	25,188
1988	275	226	7.1	1,615	12,200
1989	195	163	7.5	1,215	8,724
1990	260	253	15.1	3,812	21,108
1991	356	342	18.1	6,200	21,845
1992	171	165	19.9	3,288	13,543
1993	206	191	18.2	3,480	14,467
1994	178	171	17.1	2,922	13,655
1995 1/	165	147	15.0	2,211	N.A.
1996 2/	112	106	N.A.	N.A.	N.A.

N.A. = Not available.

1/ Preliminary. 2/ Forecast.

Table 16--Linseed oil, supply and disappearance, United States, 1987/88-1996/97

Year beginning June 1	Supply: Beginning stacks	Supply: Production	Supply: Total	Disappearance: Exports	Disappearance: Domestic	Disappearance: Total	Ending stocks
	--Million pounds--						
1987/88	51	217	268	8	219	227	41
1988/89	41	170	211	12	151	163	48
1989/90	48	165	213	12	164	176	37
1990/91	37	176	213	6	167	173	40
1991/92	40	182	222	12	170	182	40
1992/93	40	172	212	8	150	158	54
1993/94	54	176	228	3	162	165	63
1994/95	63	171	237	24	168	192	45
1995/96 1/	45	177	223	8	170	178	45
1996/97 2/	59	N.A.	59	9	159	168	59

N.A. = Not available.

1/ Preliminary. 2/ Forecast.

Table 17--Linseed meal, supply and disappearance, United States, 1987/88-1996/97

Year beginning June 1	Supply: Beginning stocks	Supply: Production	Supply: Imports	Supply: Total	Disappearance: Exports	Disappearance: Domestic	Disappearance: Total	Ending stocks
	--1,000 short tons--							
1987/88	2	198	2	202	59	140	199	3
1988/89	3	156	11	170	63	102	165	5
1989/90	5	153	9	167	23	139	162	5
1990/91	5	162	3	170	41	124	165	5
1991/92	5	167	0	172	40	127	167	5
1992/93	5	159	2	166	55	106	161	5
1993/94	5	160	2	167	49	113	162	5
1994/95	5	158	5	168	58	105	163	5
1995/96 1/	5	162	3	170	50	115	165	5
1996/97 2/	5	160	2	167	50	110	160	5

1/ Preliminary. 2/ Forecast.

Table 18--Industrial rapeseed, supply, disappearance, and price, United States, 1987/88-1996/97

Year beginning June 1	Supply: Beginning stocks	Supply: Production	Supply: Imports	Supply: Total	Disappearance: Exports 1/	Disappearance: Domestic	Disappearance: Total	Ending stocks	Price Minn-eapolis
	--Million pounds--								Cents/lb.
1987/88	2,198	21,981	0	24,179	0	23,072	23,072	1,107	10.0
1988/89	1,107	15,822	0	16,930	0	16,188	16,188	741	11.1
1989/90	741	19,143	0	19,885	0	19,003	19,003	882	10.5
1990/91	882	22,717	0	23,599	0	22,319	22,319	1,279	10.3
1991/92	1,279	16,146	0	17,425	0	17,158	17,158	267	10.1
1992/93	267	14,455	0	14,722	0	14,522	14,522	200	10.0
1993/94	200	7,442	0	7,642	0	7,592	7,592	50	10.2
1994/95	50	12,596	0	12,646	0	12,609	12,609	37	10.3
1995/96 2/	37	3,012	0	3,049	0	2,935	2,935	114	12.7
1996/97 3/	114	1,800	0	1,914	0	1,876	1,876	38	13.6

1/ Trade data do not distinguish between industrial and edible (canola) exports; therefore all exports were allocated to canola. 2/ Preliminary. 3/ Forecast.

Table 19--Industrial rapeseed oil, supply, disappearance, and price, United States, 1987/88-1996/97

Year beginning June 1	Supply: Beginning stocks	Supply: Production	Supply: Imports	Supply: Total	Disappearance: Exports 1/	Disappearance: Domestic	Disappearance: Total	Ending stocks	Price: Minn-eapolis
	--Million pounds--								Cents/lb.
1987/88	800	6,785	17,637	25,222	0	22,699	22,699	2,522	23.6
1988/89	2,522	6,858	35,274	44,654	0	40,188	40,188	4,465	25.6
1989/90	4,465	8,184	29,407	42,057	0	37,851	37,851	4,206	27.8
1990/91	4,206	6,960	20,406	31,571	0	28,414	28,414	3,157	24.5
1991/92	3,157	5,705	8,737	17,599	0	15,839	15,839	1,760	22.6
1992/93	1,760	3,707	11,076	16,543	0	14,889	14,889	1,654	24.4
1993/94	1,654	4,140	6,581	12,375	0	11,138	11,138	1,238	29.1
1994/95	1,238	2,346	10,864	14,448	0	13,003	13,003	1,445	29.6
1995/96 2/	1,445	836	11,614	13,895	0	12,506	12,506	1,390	28.5
1996/97 3/	1,390	769	12,364	14,523	0	13,070	13,070	1,452	27.3

1/ Trade data do not distinguish between industrial and edible (canola) exports; therefore all exports were allocated to canola. 2/ Preliminary. 3/ Forecast.

Table 20--Industrial rapeseed meal, supply, disappearance, and price, United States, 1987/88-1996/97

Year beginning June 1	Supply: Beginning stocks	Supply: Production	Supply: Imports	Supply: Total	Disappearance: Exports	Disappearance: Domestic	Disappearance: Total	Ending stocks	Price: Minn-eapolis
	--Million pounds--								Dol./ton
1987/88	300	10,624	0	10,924	0	10,711	10,711	212	152
1988/89	212	10,738	0	10,951	0	10,736	10,736	215	160
1989/90	215	12,815	0	13,030	0	12,773	12,773	256	135
1990/91	256	10,897	0	11,153	0	10,935	10,935	218	132
1991/92	218	8,933	0	9,151	0	9,017	9,017	134	137
1992/93	134	5,805	0	5,939	0	5,852	5,852	87	141
1993/94	87	6,483	0	6,570	0	6,472	6,472	97	140
1994/95	97	3,674	0	3,771	0	3,716	3,716	55	118
1995/96 1/	55	1,309	0	1,364	0	1,344	1,344	20	167
1996/97 2/	20	1,204	0	1,223	0	1,205	1,205	18	171

1/ Preliminary. 2/ Forecast.

Table 21--Total fats and oils consumption, with inedible by category, United States, 1988/89-95

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
	--Million pounds--									
1988/89	19,426.7	13,542.0	5,884.7	744.5	180.3	2,079.3	202.3	115.8	2,074.1	488.4
1989/90	20,036.0	14,382.7	5,653.3	792.0	89.5	2,143.5	222.4	157.1	1,944.7	304.1
1991	20,332.1	14,613.0	5,719.1	832.9	106.8	1,974.0	182.6	101.7	2,234.7	286.4
1992	20,751.7	14,847.3	5,904.4	738.8	123.8	2,176.5	165.5	109.4	2,041.2	549.3
1993	21,590.4	15,744.7	5,845.7	748.5	125.2	2,199.5	170.2	116.0	1,897.6	588.7
1994	22,058.7	15,373.8	6,684.9	770.0	115.1	2,272.5	240.7	219.3	2,306.2	761.1
1995	21,157.4	15,056.3	6,101.1	593.8	102.8	2,340.9	210.7	141.9	1,963.6	747.4

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 22--Castor oil consumption, with inedible by category, United States, 1988/89-95

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
	--Million pounds--									
1988/89	59.2	0.0	59.2	d	4.8	0.0	4.5	6.2	0.0	43.2
1989/90	51.4	0.0	51.4	d	5.9	0.0	4.0	5.7	0.0	d
1991	46.0	0.0	46.0	d	5.9	0.0	4.0	d	0.0	31.7
1992	41.3	0.0	41.3	d	d	0.0	3.3	3.5	0.0	28.4
1993	54.2	0.0	54.2	d	d	0.0	3.5	2.8	0.0	37.8
1994	61.9	0.0	61.9	d	d	0.0	1.9	2.4	0.0	41.0
1995	62.6	0.0	62.6	d	d	0.0	1.2	2.7	0.0	40.4

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 23--Cacanut ail consumptian, with inedible by category, United States, 1988/89-95

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1988/89	688.8	211.2	477.6	130.6	1.4	d	14.6	d	121.9	206.6
1989/90	525.2	160.6	364.6	156.9	2.1	0.0	9.7	4.0	134.6	57.3
1991	815.6	153.0	662.6	158.0	d	d	2.4	d	426.7	72.8
1992	875.4	176.3	699.1	121.7	d	0.0	3.2	d	d	d
1993	936.3	218.0	718.3	132.0	d	0.0	3.1	d	d	d
1994	969.2	227.1	742.1	146.1	d	0.0	2.3	d	d	d
1995	676.1	252.2	625.9	92.3	d	0.0	2.3	0.0	d	d

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 24--Inedible tallow consumption, with inedible by category, United States, 1988/89-95

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1988/89	3,086.7	0.0	3,086.7	374.9	0.0	1,925.4	0.0	70.3	680.0	36.1
1989/90	3,219.0	0.0	3,219.0	398.4	0.0	1,982.9	0.0	109.0	684.0	44.7
1991	2,949.3	0.0	2,949.3	391.5	0.0	1,748.4	0.0	59.6	700.9	48.9
1992	3,050.1	0.0	3,050.1	334.4	0.0	1,954.4	0.0	63.2	659.0	39.1
1993	3,018.2	0.0	3,018.2	299.6	0.0	1,994.7	0.0	71.5	615.1	37.3
1994	3,189.9	0.0	3,189.9	300.8	0.0	2,101.9	0.0	81.8	634.0	71.4
1995	3,222.8	0.0	3,222.8	263.9	0.0	2,166.5	0.0	89.7	656.9	45.8

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 25--Lard consumption, with inedible by category, United States, 1988/89-95

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1988/89	389.9	324.5	65.4	0.0	0.0	d	0.0	d	d	d
1989/90	369.3	303.8	65.5	d	0.0	d	0.0	9.1	d	d
1991	393.1	313.8	79.3	0.0	0.0	d	0.0	5.7	d	4.1
1992	479.7	345.0	134.6	0.0	0.0	d	0.0	10.9	d	13.5
1993	473.3	324.6	149.7	0.0	0.0	d	0.0	8.6	d	28.7
1994	451.9	324.7	127.2	0.0	0.0	0.0	0.0	8.9	0.0	118.3
1995	488.7	364.3	124.4	0.0	0.0	0.0	0.0	27.2	0.0	97.2

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 26--Linseed oil consumption, with inedible by category, United States, 1988/89-95

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1988/89	154.9	0.0	154.9	0.0	101.6	0.0	23.1	d	d	28.2
1989/90	110.5	0.0	110.5	0.0	30.3	d	52.5	d	d	23.8
1991	95.8	0.0	95.8	0.0	40.7	0.0	41.6	d	d	12.7
1992	154.4	0.0	154.4	0.0	69.0	0.0	31.3	d	d	d
1993	125.8	0.0	125.8	0.0	66.9	0.0	25.4	d	d	d
1994	124.3	0.0	124.3	0.0	33.0	0.0	50.9	d	d	40.4
1995	112.8	0.0	112.8	0.0	30.2	0.0	51.4	0.0	0.0	31.2

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 27--Rapeseed oil consumption, with inedible by category, United States, 1989/90-95 1/

Year 2/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 3/	Fatty acids	Other products
					--Million pounds--					
1989/90	d	265.0	d	0.0	d	d	d	d	d	d
1991	d	285.1	d	0.0	0.0	d	0.0	d	d	d
1992	d	360.5	d	0.0	0.0	d	0.0	d	d	d
1993	d	362.5	d	0.0	0.0	0.0	0.0	d	d	d
1994	d	446.3	d	0.0	0.0	0.0	0.0	d	d	d
1995	d	315.8	d	0.0	0.0	0.0	0.0	0.0	0.0	d

d = Data withheld to avoid disclosing figures for individual companies.

1/ Includes both canola and industrial rapeseed. 2/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 3/ Includes similar oils.

Source: Bureau of Census.

Table 28--Soybean oil consumption, with inedible by category, United States, 1988/89-95

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1988/89	9,917.6	9,635.8	281.8	1.5	34.9	d	123.7	d	d	68.2
1989/90	10,808.3	10,536.7	271.6	d	38.2	d	112.4	d	d	52.4
1991	11,267.7	10,966.7	301.0	d	49.2	d	104.7	d	d	40.4
1992	11,471.6	11,168.7	302.8	d	43.5	22.3	94.0	5.9	d	69.8
1993	12,495.6	12,200.9	294.7	d	38.7	23.7	98.1	5.8	d	65.8
1994	12,474.1	12,157.8	316.3	d	47.6	d	119.6	d	d	91.9
1995	12,354.0	12,049.3	304.7	d	47.0	d	122.4	0.0	d	99.6

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 29--Tall oil consumption, with inedible by category, United States, 1988/89-95

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1988/89	1,234.3	0.0	1,234.3	8.3	31.8	0.0	18.0	8.1	1,157.3	10.8
1989/90	1,024.7	0.0	1,024.7	8.4	7.4	0.0	21.7	7.1	969.9	10.2
1991	940.0	0.0	940.0	3.5	5.4	0.0	11.6	4.0	906.5	9.0
1992	883.5	0.0	883.5	d	d	0.0	19.4	7.0	841.8	11.4
1993	891.8	0.0	891.8	d	d	0.0	23.0	6.3	806.9	d
1994	1,362.5	0.0	1,362.5	d	d	0.0	48.4	6.1	1,025.0	d
1995	1,357.7	0.0	1,357.7	d	d	0.0	16.0	7.9	908.5	d

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 30--Tung oil consumption, with inedible by category, United States, 1988/89-95

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1988/89	7.7	0.0	7.7	0.0	3.5	0.0	1.8	0.0	0.0	2.4
1989/90	8.9	0.0	8.9	0.0	2.7	0.0	3.8	0.0	0.0	2.4
1991	6.4	0.0	6.4	0.0	d	d	2.9	0.0	0.0	1.6
1992	7.3	0.0	41.3	d	d	0.0	3.3	3.5	0.0	28.4
1993	11.2	0.0	11.2	d	1.0	0.0	8.6	0.0	0.0	1.6
1994	9.3	0.0	9.3	d	1.2	0.0	6.6	2.4	0.0	1.5
1995	20.2	0.0	20.2	0.0	d	0.0	d	0.0	0.0	12.1

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 31--Castor oil prices, raw No. 1, tanks, Brazilian, 1990-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Cents/pound --						
1990	54.50	53.50	52.60	52.00	51.20	51.00	51.00	51.00	45.00	42.40	39.63	39.63
1991	39.30	36.00	36.75	37.00	37.00	36.50	35.50	35.00	35.00	35.40	35.00	37.50
1992	37.50	37.50	37.50	36.00	34.50	34.50	34.50	34.50	34.00	34.00	34.00	34.00
1993	34.00	32.00	32.00	32.00	37.00	37.00	37.00	37.00	38.50	44.00	44.00	44.00
1994	44.00	41.75	41.00	41.00	46.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00
1995	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00
1996	43.50	41.50	41.50	41.50	41.50	41.50	41.50					

Source: Chemical Marketing Reporter.

Table 32--Coconut oil prices, crude, tanks, f.o.b. New York, 1990-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Cents/pound --						
1990	24.31	23.69	22.10	21.63	21.30	20.31	19.16	18.58	18.26	18.18	20.45	20.13
1991	20.22	20.31	20.50	19.38	19.69	21.69	26.19	25.63	25.63	28.50	31.50	32.38
1992	39.33	36.00	34.57	34.75	33.56	32.13	29.63	27.31	27.88	26.94	27.00	25.50
1993	24.94	24.33	23.65	23.25	24.13	24.95	25.35	25.61	24.44	23.88	25.62	33.06
1994	30.30	30.94	29.56	30.19	29.45	30.25	29.56	30.35	30.63	30.60	34.19	33.69
1995	32.50	32.00	31.13	31.00	30.50	35.00	37.90	35.63	35.00	36.00	37.88	33.69
1996	35.80	36.63	36.75	38.75	39.50	42.25	41.80					

Source: Chemical Marketing Reporter.

Table 33--Flaxseed, average price received by farmers, United States, 1990-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/bushel --						
1990	7.24	7.69	8.03	8.60	8.23	8.31	7.56	5.86	5.36	5.15	5.16	5.15
1991	5.12	4.80	4.90	4.66	4.33	3.98	3.91	3.69	3.55	3.40	3.31	3.46
1992	3.39	3.43	3.52	3.53	3.61	3.67	3.70	3.71	4.12	4.09	4.10	4.21
1993	4.12	4.47	4.54	4.41	4.35	4.44	4.29	3.80	4.25	4.09	4.05	4.18
1994	4.38	4.61	4.64	4.60	4.43	4.25	4.28	4.52	4.54	4.49	4.51	4.71
1995	4.76	4.94	5.15	5.10	4.93	4.25	5.10	4.52	5.11	5.20	5.13	5.03
1996	5.27	4.94	5.28	5.10	6.03	5.88	5.11					

Source: USDA, National Agricultural Statistical Service.

Table 34--Industrial rapeseed oil prices, refined, tanks, New York, 1990-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Cents/pound --						
1990	81.75	82.25	82.25	82.25	82.25	82.25	82.25	82.25	79.75	77.25	77.25	81.00
1991	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25
1992	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	67.25	62.25	62.25	62.25
1993	62.25	62.25	62.25	62.25	55.88	53.75	53.75	53.75	53.75	53.75	53.75	53.75
1994	53.75	53.75	53.75	53.75	53.75	53.75	53.75	53.75	53.75	53.75	53.75	53.75
1995	53.75	53.75	53.75	53.75	53.15	50.75	50.75	50.75	50.75	50.75	50.75	50.75
1996	50.75	50.75	50.75	50.75	50.75	50.75	50.75					

Source: Chemical Marketing Reporter.

Table 35--Inedible tallow prices, Chicago, 1990-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Cents/pound --						
1990	14.87	14.50	14.47	13.50	13.51	14.01	13.50	10.12	13.50	13.42	14.09	14.50
1991	14.53	12.91	13.63	13.57	12.25	12.36	12.96	14.00	13.50	13.68	13.08	12.50
1992	12.25	12.63	12.68	13.25	13.75	13.98	14.75	15.42	15.25	15.73	16.75	13.52
1993	15.36	14.69	15.24	15.94	15.00	15.11	14.95	14.58	14.54	14.68	14.50	14.94
1994	15.00	15.00	15.22	19.00	15.25	15.63	16.67	18.64	19.50	19.78	20.38	22.48
1995	21.75	18.86	18.00	17.75	17.50	17.89	19.61	19.81	19.53	19.46	19.75	20.08
1996	19.45	17.00	17.03	17.54	19.37	19.50	20.98					

Source: Grain and Feed Marketing News.

Table 36--Jojoba oil prices, 1 metric ton or more, f.o.b. Arizona, 1990-96 1/

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/kilogram --						
1990	15.25	20.02	20.02	20.02	20.02	20.02	26.00	26.00	25.00	25.00	24.00	24.00
1991	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	21.00	15.50	15.50	15.50
1992	15.50	15.50	15.50	15.50	15.50	15.50	15.50	13.50	13.50	11.99	11.99	11.99
1993	11.99	11.99	11.99	11.99	12.00	12.00	12.00	12.00	10.02	10.02	10.02	10.02
1994	10.02	10.02	9.01	9.01	9.01	9.01	9.01	9.01	9.01	9.01	9.01	8.48
1995	8.48	8.48	8.48	8.48	8.48	8.48	8.48	8.48	8.48	8.48	8.48	8.48
1996	5.30	4.00	4.00	4.00	4.00	4.00	4.00					

1/ Price quotes are the low end of a range.

Source: Chemical Marketing Reporter.

Table 37--Linseed oil prices, tanks, Minneapolis, 1990-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Cents/pound --						
1990	40.00	40.00	41.60	42.00	42.00	43.00	44.00	40.40	39.75	36.80	36.00	36.00
1991	36.00	36.00	36.00	36.00	36.50	36.00	36.00	36.00	36.00	30.00	30.00	30.00
1992	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	32.00	32.00	32.00	32.00
1993	32.00	32.00	32.00	32.00	32.00	28.50	32.00	32.00	32.00	32.00	32.00	32.00
1994	32.00	32.00	32.00	32.00	32.00	32.00	30.31	32.00	32.00	33.50	35.00	35.00
1995	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.50	37.00	37.00	37.00	37.00
1996	37.00	37.00	37.00	37.00	37.00	37.00	37.00					

Source: Grain and Feed Marketing News.

Table 38--Linseed meal prices, bulk, 34 percent protein, Minneapolis, 1990-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/ton --						
1990	132.50	124.50	126.25	133.75	143.00	142.50	136.00	126.25	116.25	133.00	143.75	133.50
1991	131.00	131.25	120.00	121.00	126.25	134.25	133.00	131.25	116.25	128.00	113.75	127.80
1992	122.00	124.00	115.00	117.50	120.00	125.00	123.50	126.25	131.00	141.25	152.50	137.40
1993	136.70	142.50	135.40	125.50	125.00	123.20	133.75	150.00	148.75	147.50	161.80	140.00
1994	140.00	130.00	126.00	125.00	125.00	111.40	114.90	111.60	N.A.	122.50	110.00	95.60
1995	82.40	85.25	90.00	94.40	85.00	85.00	92.50	95.00	112.50	131.00	151.67	143.75
1996	142.00	143.75	155.00	174.00	176.25	178.75	174.00					

N.A. = Not available.

Source: Grain and Feed Marketing News.

Table 39--Soybean oil prices, crude, tanks, f.o.b. Decatur, 1990-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Cents/pound --						
1990	19.28	20.27	22.80	23.35	24.72	25.03	24.69	25.05	24.45	22.59	21.05	21.55
1991	21.56	21.66	22.21	21.50	20.23	19.65	19.05	20.23	20.46	19.57	18.78	18.99
1992	18.77	18.88	19.74	19.00	20.15	20.71	18.82	17.87	18.28	18.36	20.10	20.52
1993	21.23	20.72	21.00	21.24	21.15	21.30	24.13	23.46	20.93	23.61	22.98	24.22
1994	29.91	28.85	29.03	27.94	29.48	29.43	27.20	25.02	24.87	24.73	24.75	24.75
1995	29.04	28.15	28.33	26.30	26.00	26.78	27.60	26.56	26.26	26.56	25.48	24.76
1996	23.69	23.65	23.60	25.82	26.54	23.81	24.16					

Source: The Wall Street Journal.

Table 40--Tung oil prices, imported, f.o.b. New York, 1990-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Cents/pound --						
1990	41.00	41.00	41.00	59.00	59.00	58.25	58.00	58.00	58.00	55.50	62.00	70.00
1991	70.00	63.00	61.50	63.00	63.00	61.50	61.00	61.00	61.00	61.00	61.00	70.00
1992	70.00	70.00	70.00	76.00	82.00	130.00	130.00	130.00	132.00	131.50	130.00	130.00
1993	130.00	130.00	130.00	130.00	117.00	130.00	130.00	130.00	107.50	100.00	94.75	93.00
1994	93.00	79.25	78.00	78.00	78.00	78.00	78.00	78.00	78.00	74.40	60.00	60.00
1995	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	48.00
1996	60.00	60.00	64.00	64.00	64.00	64.00	64.00					

Source: Chemical Marketing Reporter.

Table 41--Cedarwood oil prices, drums or cans, 1992-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
Chinese												
1992	N.A.	1.55	1.55	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
1993	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
1994	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
1995	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
1996	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78				
Texas												
1992	N.A.	3.20	3.20	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
1993	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
1994	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.70
1995	3.70	3.70	3.70	3.70	3.70	3.70	3.70	4.15	4.15	4.15	4.15	4.15
1996	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15				
Virginia												
1992	N.A.	5.25	5.25	5.35	5.35	5.35	5.35	5.35	5.50	5.50	5.50	5.50
1993	5.80	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
1994	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
1995	6.50	6.70	6.70	6.70	6.70	6.90	6.90	6.90	6.90	6.90	6.90	6.90
1996	6.90	6.90	6.90	6.90	6.90	6.90	6.90	6.90				

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 42--Citronella oil prices, drums, 1992-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
Java 1/												
1992	N.A.	1.95	1.95	2.38	2.38	2.38	2.38	2.38	2.53	2.53	2.53	2.53
1993	2.53	2.53	2.53	2.53	2.53	3.10	3.10	3.10	3.10	3.60	3.80	4.00
1994	4.00	4.30	4.30	4.15	4.15	4.15	4.15	4.75	4.75	5.00	5.50	6.00
1995	6.00	7.90	8.43	8.43	8.43	8.60	8.60	7.00	6.75	6.00	6.00	6.00
1996	5.00	4.85	4.85	4.13	4.13	4.00	4.00	3.60				
Chinese												
1992	N.A.	1.90	1.90	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
1993	2.20	2.25	2.35	2.35	2.35	3.13	3.13	3.13	3.13	3.25	3.50	4.00
1994	4.00	4.20	4.20	4.05	4.05	4.05	4.05	4.40	4.40	5.00	5.40	6.10
1995	7.00	7.90	8.35	8.35	8.35	8.60	8.60	7.90	6.80	6.30	5.90	5.90
1996	5.90	5.50	5.50	4.60	4.30	4.15	4.00	3.60				

N.A. = Not available. 1/ Beginning August 1995, Sri Lanka, ordinary.

Source: Chemical Marketing Reporter.

Table 43--Eucalyptus oil prices, Chinese, 80 percent, 1992-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
1992	N.A.	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08
1993	2.88	2.88	2.88	2.88	2.88	2.63	2.63	2.63	2.63	2.63	2.63	2.63
1994	2.63	2.63	2.63	1.90	1.90	1.90	1.90	2.00	2.00	2.00	2.00	2.15
1995	2.38	2.50	2.50	2.80	3.00	3.20	3.20	3.20	2.90	2.90	2.90	2.90
1996	3.00	2.90	2.90	2.70	2.50	2.50	2.50	2.50				

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 44--Grapefruit oil prices, drums, 1992-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
Florida												
1992	N.A.	5.00	5.00	5.25	5.25	5.25	5.25	5.50	4.95	4.95	4.95	4.95
1993	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
1994	6.00	6.00	6.00	6.75	6.75	6.75	7.50	8.25	8.25	8.25	8.25	8.25
1995	8.25	8.25	8.25	11.25	11.25	11.25	11.25	11.25	15.75	15.75	15.75	17.00
1996	17.00	17.00	17.00	17.00	17.50	17.50	17.50	17.50				
Israeli												
1992	N.A.	4.25	4.25	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13	4.13
1993	N.A.	N.A.	N.A.	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63
1994	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63
1995	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	13.50
1996	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50				

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 45--Lemon oil prices, 1992-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
Argentinean												
1992	N.A.	9.50	9.50	9.50	9.50	9.50	9.50	9.50	10.25	10.25	10.25	10.25
1993	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25
1994	10.25	11.00	11.00	11.00	11.00	11.00	11.50	11.50	11.50	11.50	11.50	12.25
1995	12.25	12.25	12.25	12.25	12.25	12.25	12.25	12.65	12.65	12.65	12.65	12.65
1996	12.65	12.65	12.65	12.65	12.65	12.65	12.65	12.65				
California, U.S. Pharmacopeia, drums												
1992	N.A.	8.93	8.93	8.93	8.93	8.93	10.50	10.50	10.50	10.50	10.50	10.50
1993	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	9.50
1994	9.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50
1995	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	9.00
1996	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00				
Italian												
1992	N.A.	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
1993	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
1994	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
1995	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	15.00
1996	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00				

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 46--Lime oil prices, distilled, Mexican, drums, 1992-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
1992	N.A.	9.75	9.75	9.75	9.75	9.75	9.75	9.75	10.25	10.25	10.25	10.25
1993	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25
1994	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.75	10.75	10.75	10.75	10.75
1995	10.75	10.75	10.75	10.75	10.75	10.75	12.00	13.50	13.50	13.50	13.50	13.50
1996	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50				

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 47--d-Limonene prices, drums, 1992-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
1992	N.A.	0.70	0.70	0.73	0.73	0.73	0.73	0.78	0.78	0.78	0.78	0.78
1993	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
1994	0.78	0.78	0.78	0.83	0.83	0.83	0.83	0.83	0.83	1.05	2.00	2.00
1995	2.00	2.00	2.35	2.35	3.00	3.00	3.00	2.50	2.50	2.50	2.50	2.35
1996	2.10	1.80	1.80	1.50	1.40	1.30	1.25	0.95				

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 48--Menthol prices, natural, Chinese, drums, 1992-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
1992	N.A.	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58	7.58
1993	6.35	5.68	5.68	5.10	5.10	5.10	5.10	5.10	5.10	5.00	5.00	5.00
1994	5.00	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	9.50	11.50	12.00
1995	12.00	12.50	11.00	9.75	9.75	9.00	9.00	9.00	9.80	10.63	12.00	12.00
1996	12.00	12.00	12.75	13.00	13.00	13.00	13.00	15.50				

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 49--Orange oil prices, 1992-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
California, distilled, cans, f.o.b. plant												
1992	N.A.	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
1993	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
1994	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	2.00	2.00
1995	2.00	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.88
1996	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88				
Florida, drums 1/												
1992	N.A.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
1993	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
1994	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	1.10	2.00	2.00
1995	2.00	2.25	2.50	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75
1996	2.38	2.13	2.13	1.85	1.70	1.70	1.80	1.05				
Brazilian 2/												
1992	N.A.	0.80	0.80	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
1993	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
1994	0.75	0.75	0.75	0.78	0.78	0.78	0.78	0.78	0.78	1.10	2.00	2.00
1995	2.00	2.40	2.40	2.55	2.70	2.70	2.70	2.43	2.63	2.63	2.63	2.63
1996	2.25	2.00	2.00	1.60	1.45	1.45	1.40	1.10				

N.A. = Not available.

1/ Florida, midseason, drums beginning in February 1994. 2/ Pera Brazil, drums, f.o.b. plant beginning in February 1994.

Source: Chemical Marketing Reporter.

Table 50--Peppermint oil prices, 1992-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
Midwest U.S.												
1992	N.A.	18.00	14.50	14.50	14.50	14.50	14.50	14.50	13.35	13.35	13.35	13.35
1993	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.50	13.50	13.50
1994	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50
1995	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50
1996	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50				
Yakima U.S.												
1992	N.A.	15.00	13.50	13.50	13.50	13.50	13.50	13.50	12.30	12.30	12.30	12.30
1993	12.30	12.30	12.30	12.30	12.30	12.30	12.30	12.30	12.30	15.00	15.00	15.00
1994	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
1995	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
1996	13.00	13.00	13.00	13.00	13.00	12.50	15.00	15.00				
Yakima U.S.												
1992	N.A.	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
1993	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	10.00	10.00	10.00	10.00
1994	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
1995	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
1996	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00				

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 51--Spearmint oil prices, 1992-96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
Far West, native												
1992	N.A.	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
1993	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	11.00	11.00	11.00
1994	11.00	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50
1995	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50
1996	13.70	13.70	13.70	14.70	14.70	14.70	14.70	14.70				
Far West, Scotch												
1992	N.A.	20.00	16.00	15.00	15.00	15.00	15.00	13.00	14.40	14.40	14.40	14.40
1993	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	12.50	12.50	12.50
1994	12.50	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00
1995	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00
1996	16.50	16.50	16.50	19.00	19.00	19.00	19.00	19.00				
Chinese, 80 percent												
1992	N.A.	27.50	27.50	26.40	26.40	26.40	26.40	26.40	26.40	26.40	26.40	26.40
1993	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
1994	7.50	7.50	7.50	7.50	7.50	5.75	5.75	5.75	5.75	5.75	5.50	6.00
1995	6.00	6.70	6.70	6.70	7.00	7.00	7.00	7.50	8.50	8.50	9.25	9.25
1996	9.25	9.25	9.25	9.25	9.25	9.25	10.15	11.60				

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 52--Selected prices for biobased chemicals and derivatives, 1990-96 1/

Item	Unit	Average annual price 2/						
		1990	1991	1992	1993	1994	1995	1996 3/
Starches, sugars, and gums								
Arabic gum, National Formulary, powdered, barrels	Dollars/pound	1.85	1.85	2.67	3.44	4.00	4.00	1.38
Denatured alcohol, ethyl (ethanol), CD18, CD19, tanks, delivered east	Dollars/gallon	2.11	2.08	2.02	2.02	2.26	2.46	2.67
Dextrin, corn, canary dark, paper bags, carload, works	Cents/pound	32.00	32.00	32.00	32.00	32.00	32.00	32.00
Dextrose, hydrated, commercial, bags, carload, delivered New York	Cents/pound	25.50	25.50	25.50	25.50	25.50	25.50	25.50
Furfural, tanks, f.o.b. plant	Cents/pound	77.33	79.00	79.00	79.00	79.00	79.00	79.00
Guar gum, industrial, high viscosity, bags, carload, f.o.b. shipping point	Cents/pound	35.00	35.00	35.00	35.00	39.92	53.33	70.00
Karaya gum, No. 1, powdered, drums	Dollars/pound	3.31	3.25	3.25	3.25	3.25	3.25	3.25
Locust bean gum, powdered, bags	Dollars/pound	4.75	4.75	4.75	4.63	4.71	10.00	16.00
Pectin, high methoxyl	Dollars/pound	3.30	3.30	4.03	4.75	4.75	4.67	4.50
Sorbitol, U.S. Pharmacopeia, regular, 70-percent aqueous, drums, carload, f.o.b. shipping point	Cents/pound	40.17	33.29	33.00	33.00	33.00	33.00	27.38
Sucrose acetate isobutyrate, 90-percent, drums, truckload, delivered	Dollars/pound	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Sucrose octa-acetate, denaturing grade, 100-pound drums, f.o.b. works	Dollars/kilogram	12.50	12.50	12.50	12.50	12.50	12.50	12.50
Tragacanth gum, No. 1, ribbons, 100-pound drums	Dollars/pound	36.00	36.00	36.00	36.83	41.00	41.00	41.00
Xanthan gum, food grade, 100-pound drums, f.o.b. works	Dollars/pound	5.65	5.65	5.65	5.74	6.20	6.20	6.20
Fats, oils, and waxes								
Beeswax, refined, bleached, white bricks, 100-pound cartons	Dollars/pound	3.10	3.10	3.12	3.35	3.33	3.31	3.28
Butyl stearate, technical, tanks, f.o.b. works	Cents/pound	55.00	55.00	55.00	54.75	54.00	54.00	54.00
Capryl alcohol, secondary, 98-percent, tanks, f.o.b. works	Cents/pound	43.00	48.00	48.00	48.00	66.33	68.00	68.00
Caprylic acid, commercial, pure, tanks	Cents/pound	78.33	83.00	90.92	102.00	102.00	102.00	102.00
Carnauba wax, Parnahyba, No. 1, yellow, bags, ton lots	Dollars/pound	2.50	2.88	3.23	3.50	3.50	4.88	4.25
Glycerine, natural, refined, U.S. Pharmacopeia, 99.7-percent, tanks, delivered	Cents/pound	75.92	64.00	56.63	64.08	100.75	108.00	103.63
Lecithin, unbleached, bulk, less carload, works	Cents/pound	35.00	29.00	28.00	25.75	25.00	25.00	25.00
Magnesium lauryl sulfate, tanks, f.o.b.	Cents/pound	43.00	43.00	43.00	47.75	57.25	57.25	57.25
Magnesium stearate, bulk	Dollars/pound	1.16	1.16	1.16	1.20	1.20	1.20	1.20
Menhaden oil, bulk, Gulf ports	Cents/pound	10.94	13.13	15.83	16.54	16.50	16.50	16.50
Myristic acid, commercial, pure, bags, truckload	Dollars/pound	0.79	0.67	1.10	1.25	1.17	1.15	1.15
Oleic acid, double distilled (white), tanks	Cents/pound	54.00	54.00	54.00	60.42	61.00	61.00	61.00
Sebacic acid, chemically pure, bags, carload, works	Dollars/pound	2.05	2.05	2.05	2.05	2.05	2.05	2.05
Sodium lauryl sulfate, 30-percent, drums, truckload, f.o.b. works	Cents/pound	43.00	43.00	43.00	47.75	57.25	57.25	57.25
Tallow fatty acids, technical, tanks, delivered	Cents/pound	29.00	24.88	23.50	23.50	23.50	23.50	23.50
Animal products								
Casein, acid precipitated, ground, 30-mesh, edible, imported, truckload, c.i.f.	Dollars/pound	2.50	2.50	2.52	2.55	2.55	2.55	2.55
Gelatin, edible, 100 AOAC test, drums, less truckload, delivered	Dollars/pound	1.50	1.54	1.68	1.70	1.70	1.70	1.81
Glue, bone, extracted, green, 85 jellygrams, bags, carload	Cents/pound	95.00	95.00	94.00	89.00	89.00	89.00	89.00
Lanolin, anhydrous, pharmaceutical, 400-pound drums, works	Dollars/pound	1.01	1.00	1.25	1.25	1.25	1.25	1.25
Forest products								
a-Pinene prices, technical grade	Cents/pound	43.00	43.00	43.00	52.00	60.00	60.00	60.00
b-Pinene 4/	Cents/pound	55.00	55.00	55.00	4/	114.00	114.00	135.75
Cellulose acetate, powdered, bags, truckload, delivered east	Dollars/pound	1.58	1.62	1.94	2.12	2.12	2.12	2.12
Tall oil, crude, Southeast, tanks, freight equaled	Dollars/ton	135.42	159.17	150.83	119.17	121.25	156.67	157.50
Turpentine prices, crude sulfate, tanks, f.o.b. Southeast	Dollars/gallon	1.75	1.36	0.88	0.68	0.50	0.63	1.0625

See next page for footnotes and definitions.

1/ Spot and/or list prices from the Chemical Marketing Reporter for selected chemicals and related materials on a New York or other indicated basis. These prices do not represent bid, asked, or actual transaction prices. Variations from these prices may occur for differences in quantity, quality, and location. 2/ Some prices are from the low end of range. 3/ January to August. 4/ Price changed from technical grade to 97 percent perfume and flavor grade in October 1993.

Chemical definitions:

Arabic gum is a dried, water-soluble exudate from the stems of *Acacia senegal* and related species that is used in pharmaceuticals, adhesives, inks, textile printing, cosmetics, and confectionery and food products.
Denatured ethyl alcohol is made by yeast fermentation of carbohydrates or by hydrolysis of ethylene for solvents, cosmetics, and as an oxygenated gasoline additive.
Dextrin is obtained by heating acidified dry starch for adhesives and paper products.
Dextrose is obtained from cornstarch hydrolysis for use in foods and as a fermentation substrate.
Furfural is obtained by steam distillation of acidified plant materials for polymers and foundry binders.
Guar gum is a water-dispersible hydrocolloid from the seeds of the guar plant that is used in foods and industrial applications such as oil-well fracturing fluids.
Karaya gum is a hydrophilic polysaccharide from Indian trees of the genus *Sterculia* for use in pharmaceuticals, textile coatings, ice cream and other food products, and adhesives.
Locust bean gum is a polysaccharide plant mucilage from seeds of *Ceratonia siliqua* used in cosmetics, textiles sizings and finishes, and drilling fluids, and in foods as a stabilizer, thickener, and emulsifier.
Pectin is obtained from citrus fruit rinds for use in jellies, foods, cosmetics, and drugs.
Sorbitol is obtained by hydrogenation of glucose for foods, cosmetics, and polyester polymers.
Sucrose acetate isobutyrate is made by controlled esterification of sucrose with acetic and isobutyric anhydrides for hot-melt coating formulations and extrudable plastics.
Sucrose octa-acetate is used as a plasticizer for cellulose esters and plastics, and in adhesive and coating compounds.
Tragacanth gum is polysaccharides from *Astragalus* bushes for use in pharmaceutical emulsions, adhesives, leather dressing, textile printing and sizing, dyes, and printing inks.
Xanthan gum is a synthetic, water-soluble polymer made by fermentation of carbohydrates for use in drilling fluids, ore floatation, foods, and pharmaceuticals.
Beeswax is a byproduct of honey production used for cosmetics and candles.
Butyl stearate is obtained by alcoholysis of stearin or esterification of stearic acid with butanol for use in polishes, special lubricants, and coatings and as a plasticizer and emollient in cosmetics and pharmaceuticals.
Capryl alcohol is obtained by distilling sodium ricinoleate, a castor oil derivative, with an excess of sodium hydroxide for solvents, plasticizers, wetting agents, and petroleum additives.
Caprylic acid is a fatty acid obtained from coconut oil for use in synthesizing dyes, drugs, perfumes, antiseptics, and fungicides.
Carnauba wax is a hard commercial wax obtained from leaves of *Copernica cerifera* for shoe, furniture, and floor polishes; leather finishes; varnishes; electric-insulating compounds; and carbon paper.
Glycerine is a byproduct of splitting or saponification of fats and oils, or made by petrochemical synthesis for cosmetics, food, drugs, and polyurethane polymers.
Lecithin is a byproduct of soy oil extraction used as an emulsifying agent and antioxidant in foods.
Magnesium lauryl sulfate is a surfactant derived from fatty acids for use in plastics, plasticizers, textile applications, and consumer end-product manufacturing.
Magnesium stearate is a surfactant made from tropical oil fatty acids and inorganic materials for use in lubricant, adhesive, and detergent manufacturing.
Menhaden oil is obtained from menhaden fish for soaps, rubber compounding, printing inks, animal feed, and leather-dressing lubricants.
Myristic acid is obtained by fractional distillation of coconut and other vegetable oils for soaps, cosmetics, and synthesis of esters for flavors and perfumes.
Oleic acid is obtained by fractional crystallization from mixed fatty acids for candles, soaps, and synthesis of other surfactants.
Sebacic acid is made by high-temperature cleavage of castor oil for use as an intermediate chemical in the manufacture of polymers and plasticizers.
Sodium lauryl sulfate is synthesized from fatty acids for use in toothpaste and as a food additive and wetting agent for textiles.
Tallow fatty acids are made from splitting tallow for direct use as lubricants or in greases, and for separation into pure fatty acids.
Casein is a coagulated and dried milk protein for adhesives and plastics.
Gelatin is water extracted from bones and hides for photographic emulsions and food.
Glue (bone) is obtained by steam treatment and water extraction of bones for glue and mineral flotation processes.
Lanolin is extracted from wool for cosmetics, leather dressing, and lubricants.
a-Pinene and *b-Pinene* are chemical intermediates fractionated from turpentine that are converted to pine oil (a-Pinene), terpene resins (b-Pinene), and specialty chemicals.
Cellulose acetate is made by reacting cellulose from wood with acetic acid for rayon textiles and cigarette filters.
Tall oil (crude) is a byproduct of paper production (chemical pulping) that is refined into rosin and fatty acids.
Turpentine (crude sulfate) is obtained by steam distillation of pine gum recovered from pulping softwoods (for paper production), which is used for a- and b-pinene.

Table 53--U.S. imports of nonwood fibers, yarns, twine, and cordage, 1991-96

	Unit	1991	1992	1993	1994	1995	Jan-May 1996
Flax, raw or processed, not spun	Metric tons	55,046	48,166	47,030	55,059	66,092	31,283
Jute, raw or processed, not spun	Metric tons	5,468	6,246	7,326	7,026	5,876	2,003
Flax yarn	Kilograms	413,301	690,248	888,656	1,113,918	1,185,977	316,446
Jute yarn	Kilograms	7,489,781	5,380,531	5,046,250	4,312,393	7,888,502	212,718
Abaca, twine, and cordage	Kilograms	6,111,529	5,623,279	6,930,999	7,652,898	6,268,102	2,158,617
Jute, twine, and cordage	Kilograms	1,998,699	6,623,013	7,606,930	15,403,623	11,957,283	2,135,074
Sisal, twine, and cordage	Kilograms	76,371,329	73,056,843	71,595,465	78,704,800	84,234,676	36,813,048

Source: Department of Commerce, Bureau of the Census.

Table 54--U.S. exports of nonwood fibers, yarns, twine, and cordage, 1991-96

Item	Unit	1991	1992	1993	1994	1995	Jan-May 1996
Flax, raw or processed, not spun	Metric tons	559	3,687	121	92	302	79
Jute, raw or processed, not spun	Metric tons	3,135	1,534	1,202	2,353	2,554	701
Flax yarn	Kilograms	123,132	209,218	363,084	112,330	44,078	63,942
Jute yarn	Kilograms	604,414	591,864	575,383	236,225	101,924	42,837
Jute, twine, and cordage	Kilograms	200,323	305,873	297,794	462,136	530,599	238,585
Sisal, twine, and cordage	Kilograms	1,250,597	1,366,504	1,150,473	519,285	928,515	465,565

Source: Department of Commerce, Bureau of the Census.

Table 55--U.S. imports of selected vegetable oils, 1991-96

Item	Unit	1991	1992	1993	1994	1995	Jan-May 1996
Castor oil, crude and refined	Metric tons	34,523	34,018	42,214	44,094	44,093	25,480
Coconut oil, crude and refined	Metric tons	390,994	501,466	443,496	441,332	490,650	199,360
Linseed oil, crude and refined	Metric tons	94	351	159	426	1,729	864
Jojoba oil and its fractions	Metric tons	384	235	142	198	332	59
Tung oil and its fractions	Metric tons	5,645	4,995	4,272	5,404	4,427	2,673

Source: Department of Commerce, Bureau of the Census.

Table 56--U.S. exports of selected vegetable oils, 1991-96

Item	Unit	1991	1992	1993	1994	1995	Jan-May 1996
Coconut oil, crude and refined	Metric tons	21,131	9,448	6,364	8,494	9,089	1,896
Linseed oil, crude and refined	Metric tons	4,469	3,940	3,804	5,402	15,422	3,176
Jojoba oil and its fractions	Metric tons	327	209	351	287	151	56
Tung oil and its fractions	Metric tons	500	329	297	176	516	712

Source: Department of Commerce, Bureau of the Census.

Table 57--U.S. imports of paper and pulp products, 1991-96

Item	Unit	1991	1992	1993	1994	1995	Jan-May 1996
Chemical woodpulp	Metric tons	4,085,883	4,145,682	4,435,134	4,629,028	4,948,096	1,941,156
Semichemical woodpulp	Metric tons	163,516	175,290	245,046	226,845	199,541	92,887
Mechanical woodpulp	Metric tons	126,570	107,983	145,804	199,878	160,854	42,483
Cotton linters pulp	Metric tons	1	20	10	20	206	51
Other cellulosic fiber pulps	Thou. metric tons	10,735	9,360	7,377	15,791	20,203	4,571
Newsprint	Metric tons	6,794,898	6,658,426	7,061,513	7,149,976	7,076,698	2,678,562
Writing paper with less than 10 percent mechanical pulp	Kilograms	215,221,877	248,618,324	275,800,767	190,676,102	228,337,000	69,427,904
Straw paper and paperboard	Kilograms	833	678	9,756	528,865	161	N.A.
Corrugated paper and paperboard	Kilograms	4,067,556	4,551,194	2,724,891	19,236,125	20,021,749	9,807,877

N.A. = Not available.

Source: Department of Commerce, Bureau of the Census.

Table 58--U.S. exports of paper and pulp products, 1991-96

Item	Unit	1991	1992	1993	1994	1995	Jan-May 1996
Chemical woodpulp	Metric tons	5,003,677	5,734,372	5,213,541	5,388,110	6,570,279	2,371,564
Semichemical woodpulp	Metric tons	15,291	19,578	24,885	24,450	54,013	58,931
Mechanical woodpulp	Metric tons	30,313	71,180	69,094	67,342	133,277	29,763
Cotton linters pulp	Metric tons	67,591	74,717	70,140	84,611	82,798	33,602
Other cellulosic fiber pulps	Metric tons	30,854	30,477	42,947	12,049	28,660	4,994
Writing paper with less than 10 percent mechanical pulp	Kilograms	48,753,346	74,413,780	69,953,501	116,852,248	65,107,143	41,386,095
Straw paper and paperboard	Kilograms	256,011	284,247	98,652	557,401	375,841	755,831
Corrugated paper and paperboard	Kilograms	55,948,853	48,058,868	43,613,552	41,433,989	56,858,304	29,411,101

Source: Department of Commerce, Bureau of the Census.

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